Northeastern University
College of Engineering

Cornerstone of Engineering I & II
13767 Cornerstone Engineering 1 HON SEC 36 Fall 2022 [BOS-1-TR]

Morse Code Typing Test Exhibit

SUBMITTED BY:

Braid of Chimerae

PREPARED BY:

Danny Liu
Aryan Kalaskar
Zachary Usher

Report Submitted: **December 14, 2022**

ABSTRACT

Children lack the ability to learn about spy technologies because espionage museums are scarce and are relatively inaccessible by many families because of the inaccessible location or high costs of entry. Without addressing this problem, there would be fewer people that go into the field of spy technology because of the lack of opportunities when they were a child. Therefore, MATLAB-Arduino integration and MATLAB's design app was used to create a relatively simple to create, easily portable, very interactive, strong and durable, and be safe and secure so that no one gets hurt exhibit that give kids the chance to learn how to communicate in Morse code. In addition, have them be excited about its history and applications. It should also have a maximum footprint 28in by 36in when set up and fit 40in by 30in by 12in tote bag. We also hope to be able to automatically take data from the user using MATLAB to better improve future iterations of the exhibit.

As a result, the design envisions an exhibit that simulates a typing test was, but instead of inputting letters and number, the Morse code equivalent of them. Using a button as an input, an app was created that displays letters and its corresponding Morse code to input within a time limit of thirty seconds. Afterwards, the user's statistics of "Characters per minute" and "Accuracy" is displayed. Overall, the exhibit was successful as it met most of the constraints and design goals set by the team. However, further refinements could be made to meet the ultimate vision for the project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

DANNY LIU

1.1 INTRODUCTION

PROBLEM STATEMENT

Children lack the ability to learn about spy technologies because espionage museums are scarce and are relatively inaccessible by many families because of the inaccessible location or high costs of entry. This problem impacts children who are interested in spy tech because of various pop culture media. Therefore, these children need a traveling museum of some sort that displays the cleverness of spy technology. Without addressing this problem, there would be fewer people that go into the field of spy technology because of the lack of opportunities when they were a child. As a result, our design wants to specifically focus on the topic of Morse code, specifically how to use it and its history as a language.

Using MATLAB-Arduino integration and MATLAB's design app, the functional component will mimic a typing game in which the user taps a button in forms of short and long presses to encode different letters. In our design, we wanted to keep it relatively simple to create, easily portable, very interactive, strong and durable, and be safe and secure so that no one gets hurt. It should have a maximum footprint 28in by 36in when set up and fit 40in by 30in by 12in tote bag. We also hope to be able to automatically take data from the user using MATLAB to better improve future iterations of our exhibit. The design will also be relatively autonomous; thus, it will guide the user through the interface and how the game would work. With these priorities in mind, we hope to give kids the chance to learn how to communicate in Morse code and be excited about its history and applications.

To further expand on our interactive goal as a team, we believe that a successful "interactive" exhibit should have an urge of replayability. This means that the user would want to replay the typing test to get better at the test. Repetition can help the user commit some Morse code characters into memory, thus accomplishing one of our goals for the exhibit. In addition, if the exhibit forms a healthy competition between two friends, then that accomplishes our interactive goal because it promotes replayability and the benefits of it is explained above.

STAKEHOLDERS

There are two primary stakeholders that most of the design is contextualized on: the audience, and the client. Children ranging from middle school to high school are the primary stakeholders that are going to be mainly operating and using the exhibit. This stakeholder is specifically included in the problem overview; therefore, we must always keep that audience in mind. The second primary stakeholder is the client. The client is undefined and can be any company that tasks us to create this exhibit. Since we are working directly with the client, it is important to also keep their priorities and constraints in mind as we further develop our solution.

Since this project is done in an educational setting at Northeastern University, there are secondary stakeholders within the college of engineering. The main stakeholder within this context is Professor O'Connell. One can see Professor O'Connell as a client as well since the task was given to us by him. However, we see him as a mentor that guides us through the creation of the project as if an external client has given us the task. In addition to Professor O'Connell, we have our peer mentor Justin Bonapace that serve a similar mentorship role as Professor

O’Connell. Other stakeholders also include our peers and College of Engineering faculty that acted as users of the final exhibit during the First Year Engineering Expo.

The final stakeholder is the staff at the First Year Engineering and Innovation Center (FYELIC). They are our suppliers of materials and workplace for certain aspects of the project.

SCOPE

This report will cover most of the engineering design process including research, generating solutions, prototype planning, creating, data analysis. Therefore, this report will go into detail of the research of design choices and philosophies that makes a successful educational exhibit, our varying ideas and solutions that the team came up with, our prototype planning and initial CAD drawings, creation and evolution from that initial idea, and our findings and analysis of the data collected.

This report will not cover how the question was presented because the problem was given to us by a client. In addition, we will not dive too deep into the process of creating a functional exhibit that can be shipped out into the real world because our work stops at the initial prototyping phase.

1.2 BACKGROUND

RESEARCH

Much of the research is done through online sources that outlines tips and standard practices for creating museum exhibits, specifically for children. I investigated two different design considerations, EDGE and Universal Design. Universal Design and EDGE will be explored much more in depth in a different sub-section as that is the primary design consideration we kept in mind.

EDGE is a design philosophy that have attributes that engages girls in STEM exhibits [1]. A lot of these attributes help make the exhibit comfortable for the user with considerations for space and open endedness. Therefore, the design attributes include multiple sides, space, open-ended interaction, previewability, Images, drawings, familiarity, and whimsical feel [2].

Universal Design is a philosophy that promotes inclusion. This means that knowing one's audience is important for this design philosophy. Much of what is kept in mind is those of disabilities or cognitive limitations. Therefore, the philosophy of this design is having an exhibit be accessible to everyone regardless of age, race, gender, or disability [3].

In additions to the two design philosophies there are tips for creating exhibits specifically for kids from various sources online. One of the tips was to create comparisons for less familiar objects with more familiar ones [4]. This is usually done with a comparison of everyday objects to the topic because the user can pull from past experiences to understand a complex idea. The exhibit should also engage all the senses if possible [5].

This is also a principal that is in Universal Design and this recommendation has popped up a lot of times during my research. There are various examples of exhibits that showcases spy technology like Imagine Exhibitions [6]. It was evident that many of the exhibits are game based. There is a sort of competitiveness whether it's with a timer or another person. One final tip or a series of tips is to that the user should exhibit some type of reaction. This can be done by having the user expect one thing, but something else happens [7].

In addition to the research on design tips, various spy technologies like the Enigma Machine were delved into to see what topic pursue. However, it was eventually decided to pursue Morse code and much of the research of the history of Morse code was done by Zachery Usher.

ETHICS

The main concern for this educational exhibit is the safety of the components because we kept in mind that our users are children between the ages of 12 to 18. Therefore, we are concerned about sharp edges and potentially toxic elements to the design. This also includes making sure there is no expose wires and small elements, so children won't hurt themselves as a result. In addition to safety, we are also considered the complexity of the topic being taught. If it is too complex for our audience then the value of the exhibit is worthless.

EDGE

EDGE has tips for creating exhibits that specifically keep in mind of the needs of girls as they explore topics in STEM. This includes creating multiple spaces and sides so that the user can work alone or as a group. Have an exhibit that promotes open-ended interactions. This means to not have a rigid way of interacting with the exhibit. It should also be able to watch another person experience the

exhibit. This makes it so that the user can generate curiosity for people who may be just looking.

EDGE also goes into the aesthetic nature of the exhibit. The attributes include having images and drawings to convey certain elements of the whole exhibit. For example, for instructions on how the exhibit works, having a pictorial style instruction poster can help engage the user in exhibit. In addition, utilizing familiar objects can have the user interact with the exhibit more because of nostalgic emotions. This also ties into the last point of EDGE and that it should exert a homemade feel. This can be many things with specific color palettes and different patterns. However, this can also be accomplished if familiar everyday elements are also incorporated into the design.

EDGE gives a lot of great tips and suggestions to think and consider about throughout the idea generation process as we try to cater certain ideas to fit the mold of certain attributes that is associated with EDGE.

Universal Design

Universal Design essentially states that an exhibit should be designed in a way to accommodate everyone that can potentially use it. One of the most basic and primary examples of this is to make it assessable for those in wheelchairs [3].

However, there are a lot more ideas to consider when creating an exhibit that adheres to Universal Design principals. The Universal Design principals asks the why, what and how of learning [8]. The most relevant tips and attributes for our type of project was to optimize choice and autonomy, multiple sensory stimulation, and offer different ways to learn the topic at hand. These tips focus on the different types of learners and have exhibits keep in mind of the different ways people learn things and encourages exhibit makers to try to incorporate as many as possible.

Universal Design is important to us as a group because to promote our design goal of being interactive it must be accessible to everyone. Therefore, throughout the entire process we asked if any group of people will have a hard time with the exhibit and design solutions around that.

1.3 METHODOLOGY

PROBLEM ANALYSIS

Before tackling into what the different solutions are to the problem, researched was done (see Research tab) and design goals were created. Through discussion of the individual research conducted, five design goals were created that would make a successful educational museum exhibit. Ease of creation is the ability for the team to create the exhibit within expertise, resources, and time limits within the semester. Portability is taken from the constraints and the exhibit must fit in the provided plastic bin and fit on a 28in by 36in table. Interactivity is how well and how often users interact with the exhibit. Thus, one metric for this design goal is if the functional component is replayable. Durability is how well constructed the exhibit is going to be. Therefore, the exhibit should withstand multiple uses and interactions. It should also be sturdy enough that it withstands rough travel conditions. Safety was taken from the consideration that the primary audience are children. Therefore, the exhibit must be free of any sharp edges or exposed wire so children, who are not also careful, can enjoy the exhibit without the worry of harming themselves.

In table 1, the design goals are placed in a KTDA chart that compares each design goal to one another. For example, Ease of creation is compared to Portability. After some deliberation, it is concluded that both are of equal importance because both are taken from constraints. Therefore, a "0" is put in place to represent that. Then ease of creation is compared to interactivity. Through some discussion, it is determined that interactivity is more important than ease of creation because that determines the success of the exhibit. Therefore, a "-1" is put in place to represent that. A "1" would represent that ease of creation would be more important than the priority that the column represents. It is also observed that there are "0.5" in the table. This represents that it is only slightly more important or slightly less important to each other.

As a result, from the KTDA chart [Tab. 1], Safety is the most important design goal, followed by interactivity, durability, ease of creation, and portability. Thus, these numbers influenced the weight the design goals are given. As a result, Safety was given a weight of 10, interactivity was given a 9 because their scores are only of a difference of 0.5, durability was given a 6 because it around the middle of the other scores, portability and ease of creation were given the scores of 3 and 2 respectfully because of their low score ratings.

Following the creation of the design goals, six different topics of spy technology were brainstormed and compared against the design goals that were set. As seen in table 2, those topics were, radar, Enigma Machine, Two-way mirror, Cybersecurity, Morse code game, and listening machine. Then 3 individual KTDA charts were made to compare each topic to each design goal (Appendix B). A 4th KTDA chart was made to average all the scores out [Tab. 2]. Morse code game topic scored the highest with a score of around 240. The topic of Morse code won based on its high performance in all the priorities set by the Team. The creation of the interactive aspect of a morse code exhibit is very doable since there are already a lot of resources online that can be used as a foundation [9]. The idea can be very portable because it relies much more on software than on hardware, making it relatively portable. The fact that it relies much more on software makes it both high on durability and safety because there are fewer physical parts to worry about in these respective topics. It is also believed that the topic of morse code can be interactive because it

	Ease of Creation	Portability	Interactivity	Durability	Safety	Total
Ease of Creation	-	0	-1	-1	-1	-3
Portability	0	-	-1	-0.5	-1	-2.5
Interactivity	1	1	•	0.5	0	2.5
Durability	1	0.5	-1	•	-1	-0.5
Safety	1	1	0	1	•	3

Table 1. KTDA for comparison of Design Goals.

Priority Compared To (Assigned Wt.) Topic	Ease of Creation (2)	Portability (3)	Interactivity (9)	Durability (6)	Safety (10)	Total	Total (Weighted)
Radar	3.666666667	6	6.666666667	6	8.666666667	31	208
Enigma Machine	6.333333333	7.333333333	5	4.666666667	8.333333333	31.66666667	191
Two-Way Mirror	7.666666667	4.666666667	6	5.666666667	6	30	177.3333333
Cybersecurity	4.333333333	6	6.333333333	6.666666667	6.666666667	30	190.3333333
Morse Code Game	6.666666667	6.666666667	8.333333333	8	8.333333333	38	239.6666667
Listening Machine	5.666666667	7.666666667	6	6.666666667	7.666666667	33.66666667	205

Table 2. Compiled KTDA of topics scored according to design goals.

can involve social aspects or independent aspects. Thus, giving the user the freedom to choose.

GENERATING SOLUTIONS

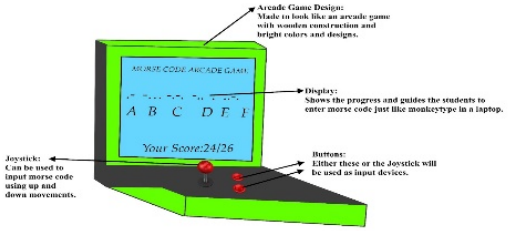


Fig. 1. Concept drawing for typing test idea.

In a brainstorming session, three rough ideas about what the interactive parts of the morse code exhibit would be was produced. The first idea was to create a morse code typing test, similarly to the website Monkey Type [Fig. 1]. The second idea was to create two stations with LED lights that two kids can communicate to each other with Morse code [Fig. 3]. The third idea was to do sequence memory in Morse code [Fig. 2].

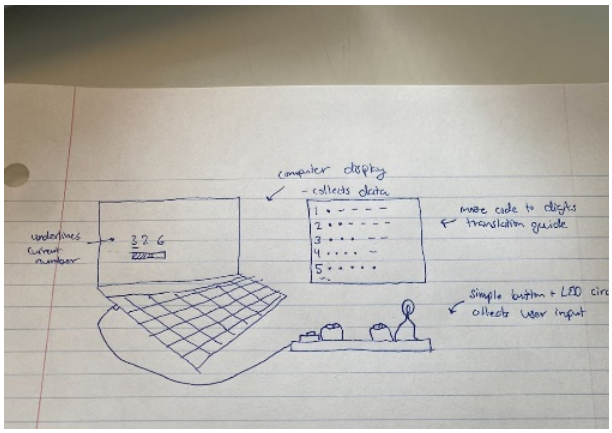


Fig. 3. Concept drawing for sequence morse code.

Then, the SCAMPER ideation technique was used to come up with four more ideas. One idea was to have the interactive component give the user a phrase in morse code, and the user would have to guess what that phrase is. This uses the reverse technique because instead of the kids physically tapping the Morse code like the other brainstormed ideas, the exhibit would be the one generating the Morse code. Also used the combine element by combining the typing test idea and sequencing idea made in the brainstorming section. This idea is like the Human Benchmark website, but in morse code. The next two ideas are adaptations of existing games but utilizing Morse code. The Team thought of having a type racer but in Morse code concept, which expands more on the typing test idea in the brain storming phase. The other idea is a rhythm game with the user inputting Morse code signals. This idea is inspired by piano tile games on the phone using morse code as the lyrics.

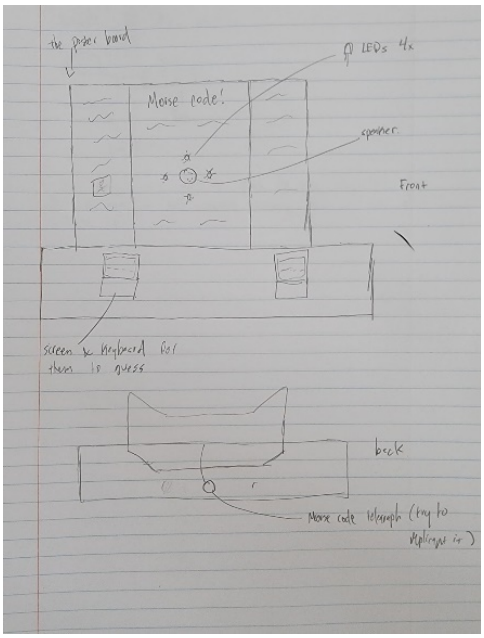


Fig. 2. Concept drawing for two kids communicating through morse code.

These ideas were then compared to the design goals that were set in the beginning of the process that was compiled in a single KTDA chart [Tab. 3]. Each score given is a

consensus score agreed on by all members of the team through discussion. As seen from table 3, all the generated ideas are relatively close, however the highest total was the Monkey Type Morse code game idea. Therefore, the design was initially modeled using figure 1 as inspiration. It was also discussed that many of the ideas are very close in score. As a result, it was decided to start off with the typing test game using morse code with the idea that it can further be expanded upon to make it into a type racer game and expanded it even more with different game options that was present in the table. Thus, the design could be built off and expand upon if there is enough time and resources.

PLANNING

Before any building was done, it was brainstormed of how the user would roughly interact with an exhibit. Therefore, it is perceived that the user will walk to the exhibit and see a high score displayed on the monitor screen. The user will want to try to beat that high score and so they will enter their name and age (so that data can be recorded) and a screen with a series of letters with the combination of the taps that corresponds to that letter at the bottom. The user will have 30 seconds to tap out as many letters as they can. At the end their score, accuracy, and compile tapping score (their accuracy times raw score) will be displayed. If they beat the high score, a celebratory screen will play, and the high score will be replaced. However, some of the details were not implemented due to time constraints.

Solidworks sketches were created to further refine the vision of what the Morse code exhibit would look like. Since a laptop would be used to run the program, it is decided to create a device that would compactly interact with the laptop so that there wouldn't be different parts scattered around the exhibit [Fig. 4]. Therefore, this device can house all the electronic components like the button that will interact with the laptop. In addition, the device can also discreetly hide all the necessary wires and USB cables so that the user cannot play around with them or potentially get hurt.

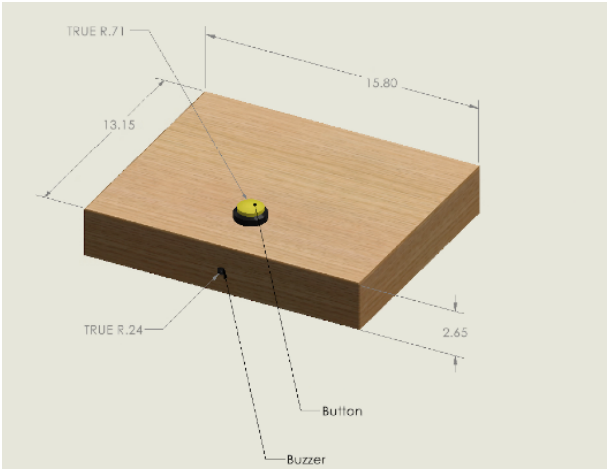


Fig. 4. Solidworks representation of the console.

This device, called the console, is slotted over a laptop computer. It is designed to fit onto a 16-inch laptop computer and has the arcade button [Appendix I] and buzzer that will be connected to a spark fun red board and breadboard.

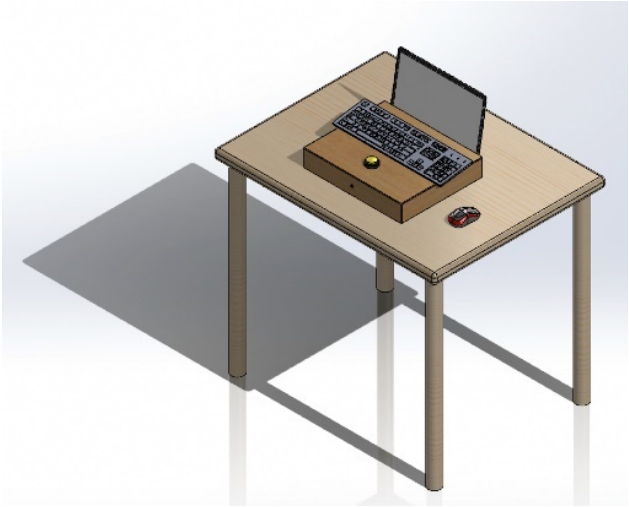


Fig. 5. Solidworks representation of the full setup of the exhibit.

	Ease of Creation	Portability	Interactivity	Durability	Safety	Total:	Weighted Total
Weight	2	3	9	6	10	•	•
Monkey Type	8	9	8	8	10	40	263
Number Memory	6	9	8	7	10	40	253
Type-racer	5	8	10	6	10	39	260
Piano tiles	4	9	10	5	10	40	255
Sequence Memory	7	8	7	6	10	38	237

Table 3. KTDA for the generated solutions scored against the design goals.

In its full setup configuration [Fig. 5], the console is designed to cover up the internal keyboard of the laptop and hide all the electronics by giving enough clearance for both components. Therefore, the height was decided to be 2.65 inches to fit both those components. In addition, a keyboard was incorporated so the user can input their information before the game starts. Also note that the poster is not being represented here because it was thought as a simplistic background that wasn't needed at the time.

Furthermore, a traveling configuration model was created to show that the design is very compact as the laptop can just be slid underneath the console [Fig. 8]. The console is also small enough because it has a 15.8 inches by 13.15 inches by 2.65 inches footprint that will fit in the plastic bin that was provided.

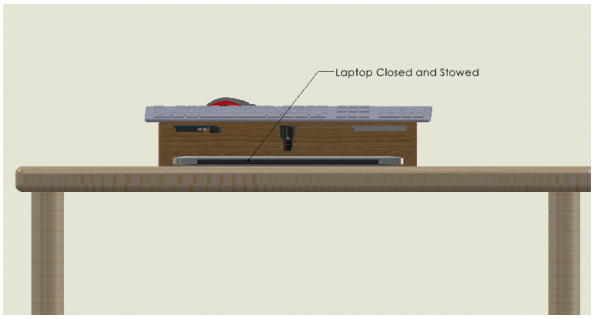


Fig. 8. Solidworks representation of exhibit in travel configuration.

In addition, a cardboard mockup of the models was created [Appendix G] to have a physical model of the design. This helps create a sense of scale and confirms the dimensions for the final design.

Initial Prototyping

At this stage, the initial prototyping took shape of the cardboard mockup, but replaced with laser cut wood and initial stages of the electronic components [Fig. 6]. Wood was chosen because it is a very durable and easy to manipulate material. It is also readily available at FYELIC

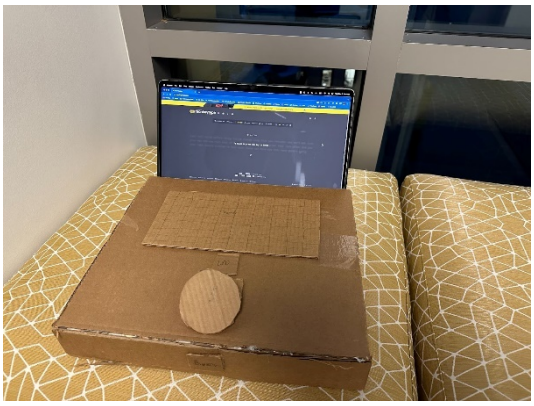


Fig. 6. Cardboard mockup of the console in its functional setup.

and the Northeastern University bookstore. Therefore, it helps make the design meet the design goals of durability and ease of creation because of the resources that were found on campus.

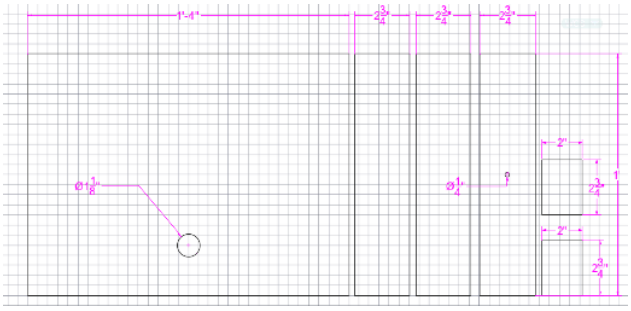


Fig. 7. AutoCAD drawing of each piece of wood to be laser cut.

A small problem arised where the wooden boards were 12 inches by 24 inches while the AutoCAD sketch called for 13.5 inches by 16 inches dimension. However, it is decided to just shrink the width to 12 inches rather than 13.5 inches because there already some tolerance for the width [Fig. 7]. In addition, the front piece containing the buzzer must also be cut into three different pieces instead of whole pieces as a result of the dimensions of the wooden boards [Fig. 7]. Another small problem the Team encountered was that the front piece was slightly smaller

than anticipated. However, it was solved by putting two dowels in the corners to cover the holes [Fig. 10].

Fig. 10. Initial prototype of the console.

Furthermore, preliminary electronics were set up with the piezoelectric buzzer being placed in the front of the console and the arcane button placed on top [Fig. 10]. A proof-of-concept circuitry was also set up underneath the console to test the initial code. This just included the buzzer and button placed where it would be and an LED light that is attached to the breadboard [Fig. 11]. The LED is attached to the breadboard because it hasn't been decided the placement of the LEDs yet and was temporarily placed on the breadboard to test the code out.

After meeting with Professor O'Connell regarding suggestions about the placement of LEDs. It was decided to have the LEDs represent when the user inputs a "dot" or "dash". This is done by having the left side of the console contain a single LED that lights up when the program recognizes a "dot" is pressed because in Morse code a dot is one unit. Then the right side of the console contains three LEDs to represent a "dash" because a dash is three units [Fig. 9]. Although that change in the design was not reflective on the Solidworks model, the laser cut wood didn't accommodate for this. Therefore, holes were drilled in with bit sizes that fit the LED bulbs.

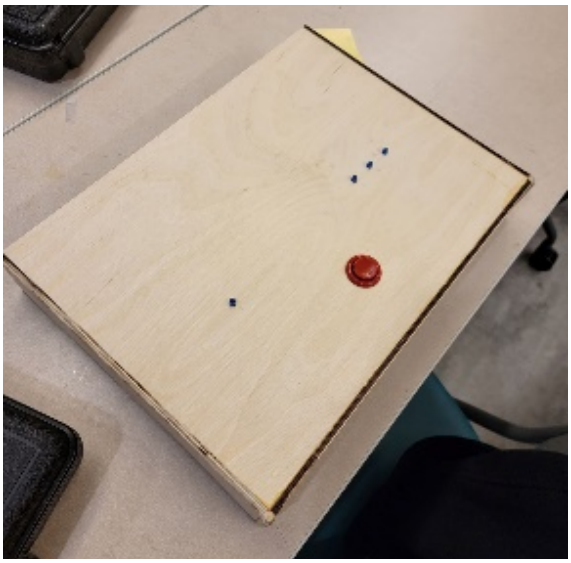


Fig. 9. console prototype with LEDs installed.

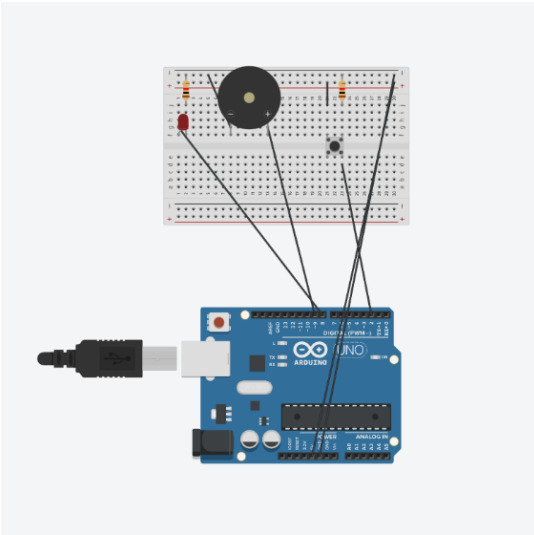


Fig. 11. Wire diagram of initial proof of concept electronics.

PROGRAMMING

A big part of the exhibit is the programming aspect because the user will be interacting specifically with the MATLAB app designer. However, a program that recognizes short and long presses and converts them to Morse code is needed and the team lacked expertise to build a program ground up. Luckily, that part of the code

was outsourced online from the author Vladimir Krsmanovic [9]. From that point, the code was modified to include code that would interact with the LEDs and arcade button installed.

A logic of the app interface was created to plan what programming work needs to be done [Fig. 12]. The app will prompt them to put in their information so that data can be collected. The game will run, and MATLAB will read from the Arduino console the Morse code that the user imputed and compares it to the correct Morse code that was displayed on screen [Appendix E]. If the user inputs the Morse code incorrectly then it will be marked incorrect and move on. At the end, MATLAB will have saved all correct and incorrect inputs the user put and display their character speed, and accuracy [Appendix E].

This is the barebone skeleton programming logic of how the app would work without any aesthetic or quality of life implementations mentioned in the generating solutions section. Therefore, implementation of having a high score screen has yet to be thought about.

After the creation of the backend of the app, the creation of the user interface was done on MATLAB's app designer. During the creation of this component, an idea of implementing a tutorial screen was brought forth. This was a good idea because it gives the user a little practice and feel of how the button and program read their inputs. This helps them understand how long the dash should be pressed [Fig. 20].

It was also decided that for the game element of the UI [Fig. 22], the user will have 30 seconds to input as many characters as possible because 30 seconds is not too long, but not too short either. It was also decided to have the characters come in order of difficulty rather than distributing them randomly. This was done to help the user ramp up their knowledge of Morse code by starting with the easier inputs first. With repeated practice, it is assumed that the user will get better, thus get further into the game and learning more complex characters slowly. In addition, it is decided that to reduce complexity, the app will only have the user input one single character at a time. Furthermore, the specific Morse code patterns are also displayed to also reduced that complexity. This was done because the primary user will be children ranging from middle school to high school. Therefore, having complex words can make the game a little too hard.

DATA COLLECTION

There are two ways in which data is collected, the first of which is autonomous in-app data collection. The app prompts the user to enter their age and grade and the user's characters per minute and accuracy are calculated and displayed to the user in the app [Fig. 23]. In addition, the app also calculates the amount of time each user took on each character and the character they inputted [Appendix D]. From this type of data, it can conclude which character was difficult for the user and the order of character appearance can be changed. In addition, analysis could be shown to showcase if certain age groups have an easier or harder time in learning a new language like Morse code. The secondary way that data is collected is by a survey linked to a QR code at the end of the typing game. The link contains a google form that field some qualitative questions on the design goals of the exhibit and a section where suggestions and comments can be made [Appendix D].

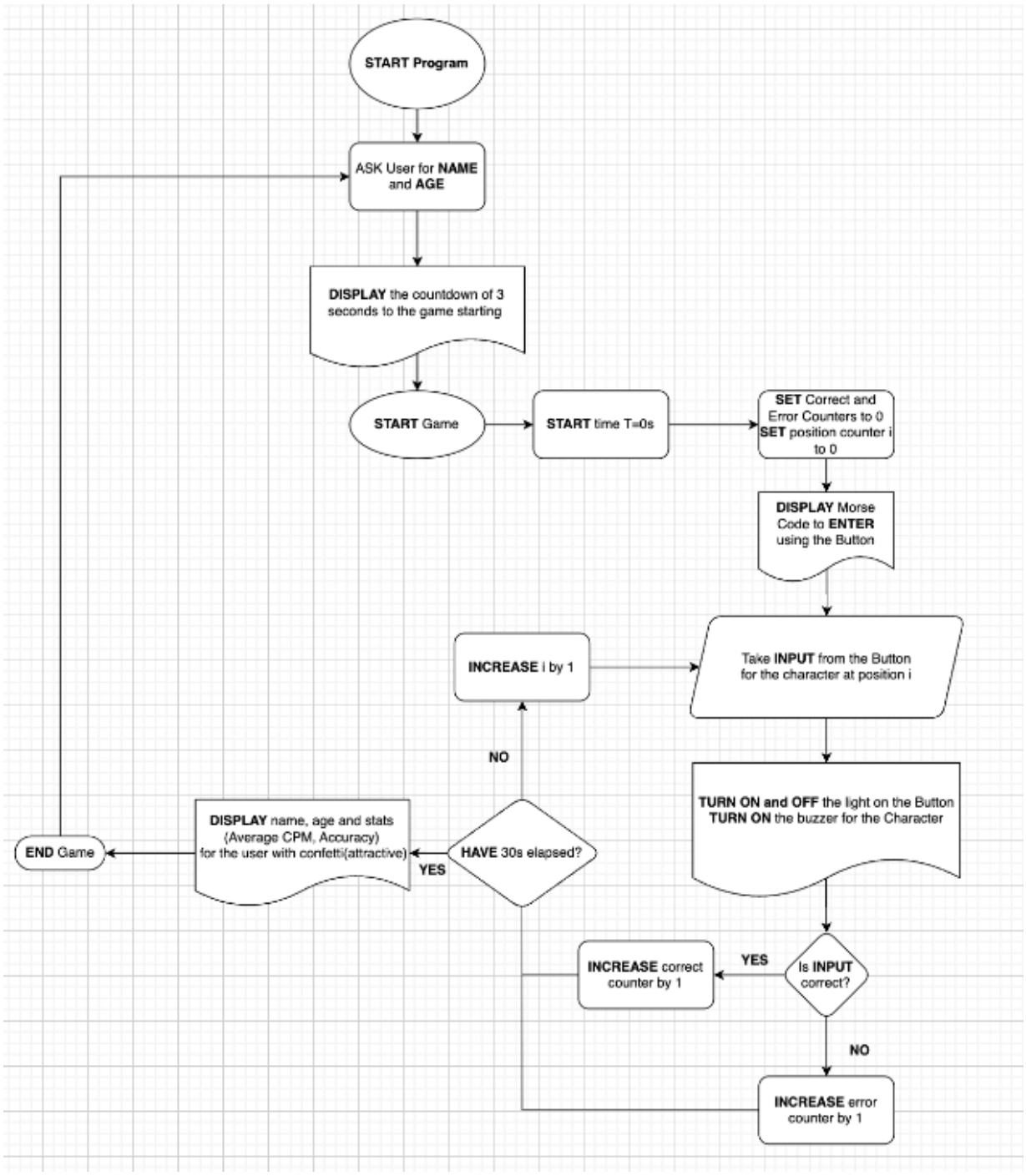


Fig. 12. Flowchart of user experience.

Final Prototype Preparation

Final aesthetic touches were made to the console that promotes a “homey” and professional feel. This includes sanding the rough edges and faces of the wood, but also wood finishing and painting the area around the LEDs [Appendix G]. However, it was concluded that the blue paint didn’t add the “homey” feel and made it look less professional. Therefore, it was decided to cover the LEDs with acrylic so it can disburse its light [Fig. 14]. Unfortunately, the design to have a keyboard was scrapped because the velcro didn’t stick each other as effectively to the keyboard. Mounting the keyboard is needed to prevent the user from playing around with it. Therefore, the data collection tab was changed to drop down boxes instead of text boxes to input their age and grade [Appendix G].

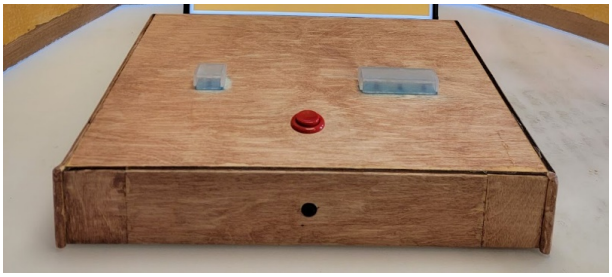


Fig. 14. Final prototype build for the console.

In addition, the electronics were finalized with the inclusion of the 4 extra LEDs and placing them in their respective spots on the console [Fig. 13]. In addition, to promote durability and safety, the wiring was soldered in place so that any connections will not accidentally come apart. Furthermore, all exposed wiring metals were covered in electrical tape to prevent shock.

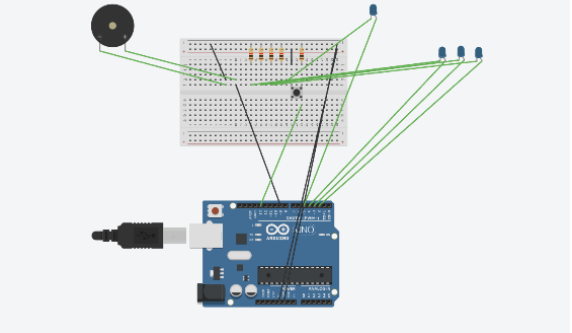


Fig. 13. Final wire diagram of the electronic components.

Finally, the poster that will act as the passive educational component was created to show case the history and technicalities of Morse code [Fig. 16]. The middle of the poster showcases the history of Morse code. It displays the how and why Morse code was created a long with some images to further emphasize that point. On the left side, it presents the technicalities of Morse code. For example, it tells the user that the dot is one unit long and the dash is 3 units long. On the right side, it tells the user some Morse code stories and its application during the two World Wars. In addition, the color of the background is gold and brown to match the color palette of the console and the blue outlines of the text was to match the blue LEDs that would light up when the button is pressed.

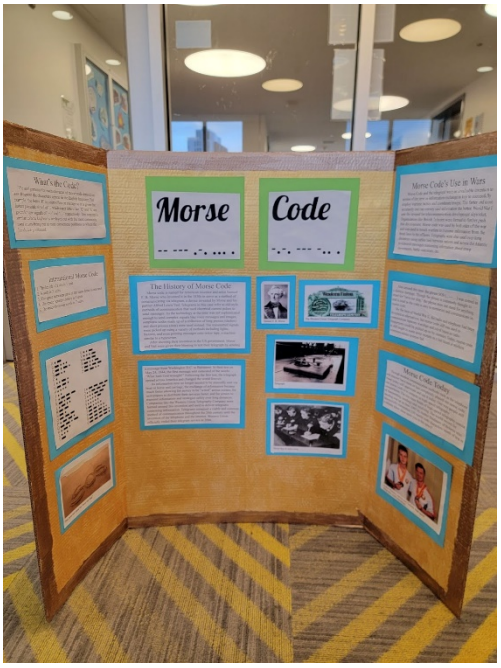


Fig. 16. The final passive educational component of the exhibit.

Individual Contributions

I drove the discussions of the comparison between the design priorities by pointing out that certain elements like "Interactivity" should be vastly more important than "Ease of Creation" or "Portability" however it may not be that much more important than certain elements like "Durability". Therefore, I suggested to have the ranking of "0.5" be included in the metric.

In addition to the initial planning stages of the prototype, I also worked mostly on the physical functional component of the exhibit. I put together parts of the console and worked on all the electronic parts of it [Fig. 15].

Therefore, I created the circuitry of the piezo buzzer, LED placements of each electronic components like having the buzzer in the front panel and the LEDs in front of the arcade button. This includes drilling holes in the console that were not depicted in the initial CAD sketches to accommodate for the LED lights. I also cleaned up the circuitry by extending the wires of the LEDs so they can be connected to the red and broad boards. Along with soldering wires into place and electrical taping exposed metal wires.

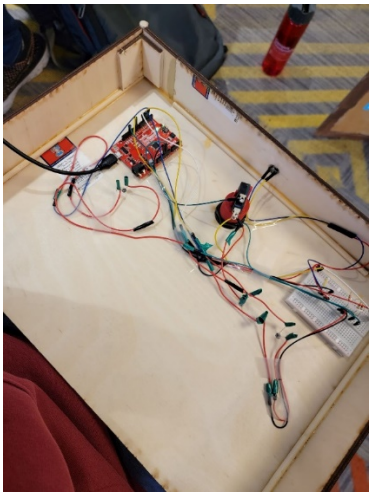


Fig. 15. Electronics and wiring underneath the console.

I also helped with some anesthetic aspects of the console by wood painting the face of the console. I also gave the idea to use Velcro to secure a keyboard onto the console. However, we further testing it did not work the way I intended it would, thus we scrapped that idea. In addition, during expedition day, I mainly presented and guided users through our exhibit.

ARYAN KALASKAR

1.4 INTRODUCTION

PROBLEM STATEMENT

Often, children do not have the opportunity to understand spy technologies because spy museums are rare and mostly located in major cities. Thus, the field of spy technology, although an interesting subject, remains unexplored by most children. It is from this that the need for a traveling museum on spy technology arises. Without such museums, the children would not be exposed to the technological advancement in spy technology. Team Chimera's project aims to make an interactive and gamified exhibit on Morse code.

The aspects of the project that were prioritized the most were safety, interactivity, durability, portability, and ease of creation listed in the order of decreasing priority. The exhibit should not have a footprint greater than 28in by 36in when set up and must fit in a 40in by 30in by 12in tote bag or box in the transport configuration. As a part of the extra credit requirements, we aimed to include an automatic data collection system. Furthermore, we aimed to make the exhibit capable of working with extremely minimal to no intervention. To work towards the minimum intervention goal, software changes were made which enabled the user to replay the game like an arcade game. Keeping these goals in mind, our project aims to teach children about Morse code, its history and its applications.

STAKEHOLDERS

One of the most important things engineers need to do is identifying and taking into consideration the point of views of stakeholders of any project. The major stakeholders of this project were the end users, who were mainly middle and high school children, and the client who commissioned this project, who aimed to have a portable spy museum exhibit for the end users (the children).

SCOPE

This report will cover most of the engineering design process including research, generating Solutions, prototype planning, creating, data analysis. Therefore, this report will go into detail of the research of design choices and philosophies that makes a successful educational exhibit; our varying ideas and solutions that the team came up with; our prototype planning and initial CAD drawings; creation and evolution from that initial idea; and our findings and analysis of the data collected.

However, this report does not explain the thought process behind the idea of the project since it was commissioned by the client. Furthermore, it will not dive too deep into the process of creating a production model or final model since the objectives of team chimera were limited only to the initial prototypes and exhibit.

1.5 BACKGROUND

RESEARCH

Some of the ideas that were considered during initial research were Stealth Plane Technology (5th Gen Aircraft) and a marble demonstration which would show how data is intercepted. However, the first spy technology that I thought of was Morse Code. Early ideas for the exhibit included a machine that would have a large button to communicate Morse code and there would be simple letters and words that they can try typing into the machine. For this idea, the users would have to enter their age and grade using a keyboard/mouse before entering the letters and words. After they try transmitting morse code, the app would show them data on how they performed compared to others and how they found communicating in morse code was.

This idea was thought of with the intention of showcasing one of the most widely used spy communicating technology from the late 19th century through this presentation. The project would even showcase how it helps disabled people to communicate [10] with just one button for the entire two-way communication process.

SAFETY

The main design goal for the exhibit was safety because its end users are high school and middle school children. Thus, sharp edges, exposed wires, ingestible pieces, and potentially toxic elements were eliminated from the design.

COMPLEXITY

In addition to safety, the complexity of the topic being taught was considered. Children, especially those below 9 years of age would not be able to enter complex words and sentences in Morse code and would thus lose interest in the exhibit. Keeping these limitations in mind, the app was designed in a way that it would require the user to input only single letters instead of words given that the users are likely to have never used Morse Code.

EDGE

EDGE has advisories on various ways in which an exhibit can cater to the aspirations and needs of girls as they explore STEM topics. Some characteristics typical of EDGE-based designs include having images and drawings to convey certain elements of the whole exhibit. From the perspective of EDGE, the idea of including a picture of female spy or personnel who used or made the device/technology on our label was considered. This can help add real world context to the exhibit, especially among girls who could envision themselves as the users/designers of such technology.

MUSEUM OF SCIENCE BOSTON

Museum of Science Boston makes exhibits interesting in a few notable and replicable ways. Firstly, it places an emphasis on the aesthetics and color combinations which makes children more interested. This can be seen in the New England Habitats exhibit [11]. The exhibit has backgrounds made of images that depict the animals' habitat and surroundings.

Additionally, some museum exhibits make use of more than one skill (motor skills, vision, perception). This can be seen in the Arctic Adventure exhibit [12]. The exhibit has different lighting hues which mimic the Sun's course and a wall made of ice. These are features that engage the visitors by invoking different senses like vision and sound.

Universal Design

Universal Design outlines the ways in which an exhibit can be designed in a way to accommodate the greatest number of users. To make the design more accessible to a diverse user base, it was designed to be 25% shorter(estimated), have more one-handed user elements than an average museum exhibit, and have displays at specific angles to create a demonstration that most students, even those with disabilities can engage in. Aiming to make the exhibit shorter was a newly introduced constraint of a sort. This constraint was introduced in accordance with Universal Design for Museum Learning Experiences [3].

1.6 METHODOLOGY

MILESTONE 1 – DEFINING THE PROBLEM

For the first milestone of this project, the team was tasked with interpreting the problem to be solved over the course of the next few weeks. This milestone served to outline client objectives, identify the stakeholders, identify, and list the constraints, and consider some aspects of good exhibits that could be replicated in the project. The main objective of this phase was to define a clear goal to move forward with. Additionally, it laid the foundation stones for the rest of the project through the formation of the resource tracking files like the Gantt Chart [Appendix H], bill of material [Appendix I], and hours log [Tab. 5] as well as beginning to use the design notebook for the second project. During this milestone, it was decided that the project would be based on spy communication.

	Aryan	Danny	Zachary	Total Work Hours
P2-Milestone 1			PM	
Complete Individual Research	2	2	2	6
Update Resource Tracking Sheets	0	0	1	1
Compile Everything	1	1	1	3
Review the Memo	2	2	2	6
Totals	5	5	6	16

Table 5. First Hours Log

MILESTONE 2 – IDEA GENERATION

During the second milestone of this project, the design goals and priorities were ranked and assigned weights using a KTDA for the quantitative aspect of decision making [Tab. 6]. Subsequently, each individual design was rated individually, keeping in mind each priority and their significance as set before [Tab. 4]. Additionally, this process enabled the team to evaluate all ideas and get to know them in depth, which proved useful in the SCAMPER method that we used later to refine the final idea to pursue.

Aryan	Topic \ Priority Compared To (Assigned Wt.)	Ease of Creation(2)	Portability(3)	Interactivity(9)	Durability(6)	Safety(10)	Total	Total(Weighted)
	Radar	4	5	7	4	9	29	200
	Enigma Machine	7	8	6	5	10	36	222
	Two-Way Mirror	9	4	4	6	5	28	152
	Cybersecurity	3	5	7	6	6	27	180
	Morse Code Game	8	7	8	8	10	41	257
	Listening Machine	4	9	6	8	9	36	227

Table 4. Aryan Kalaskar's KTDA chart for different topics

	Ease of Creation	Portability	Interactivity	Durability	Safety	Total
Ease of Creation	-	0	-1	-1	-1	-3
Portability	0	-	-1	-0.5	-1	-2.5
Interactivity	1	1	-	0.5	0	2.5
Durability	1	0.5	-1	-	-1	-0.5
Safety	1	1	0	1	-	3

Table 6. Decision Matrix for the different design goals

MILESTONE 3 – IDEA GENERATION

The third phase of this project included designing the console using CAD software [Fig. 19] and making the cardboard mockup of the exhibit according to the CAD drawings. Furthermore, it was during this phase that the anticipated list of electronics was made, and the problem statement was refined. The anticipated list of electronics served as a good source for sourcing the parts and planning the build of the prototype. Additionally, the cardboard mockup was a good tool to understand certain changes to be made to the original design [Appendix G]. One of the changes we implemented was the use of a smaller 28mm arcade button instead of the planned 45mm arcade button.

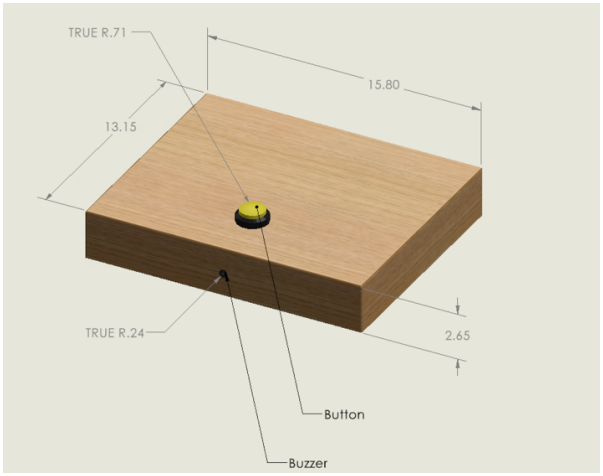


Fig. 19. CAD drawing for the console

Milestone 4 - Proof of Concept & Feedback Plan

The fourth milestone was mainly about proof of concept for the anticipated project. Major work during this phase included sourcing code for the Arduino circuit and making a circuit with a button input [Fig. 17]. Furthermore, the evaluation methods were charted out during this milestone [Appendix D].

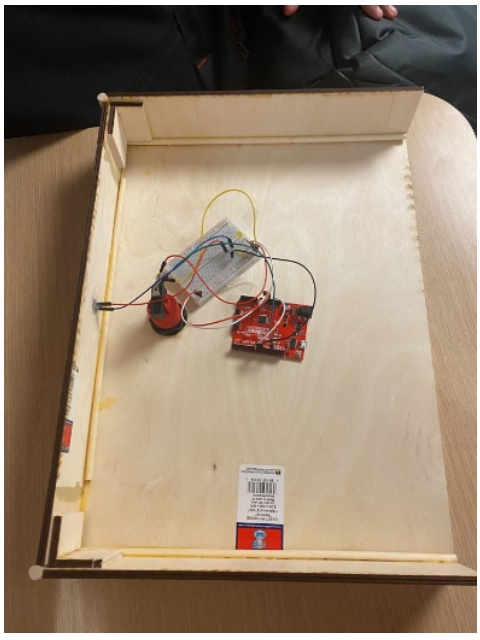


Fig. 17. Initial Circuit for proof of concept

Milestone 5 - 90% Complete Prototype and Design Review

The fifth milestone of this project entailed the most amount of work since a 90% complete prototype had to be displayed to the students for evaluation, reviews, and recommendations [Fig 18]. During the period between the fourth and fifth milestones, most of the software and hardware work was completed in addition to the posterboard for the educational part. The in-class display and peer evaluation, which was a part of this milestone, was essential in understanding new perspectives on the overall exhibit for the first time. The recommended changes given by colleagues from other teams and Prof. O'Connell were attempted and while some came through, the other changes were not implemented due to time and sourcing constraints. One of the changes that were implemented was the change in the color of the GUI from blue to a gold which blended with the rustic look of the entire exhibit. One of the changes that were attempted but not implemented completely was the use of brighter RGB LEDs as used by the Finery of Sphinxes in their memory game. The LED lights change was not implemented largely due to time constraints.

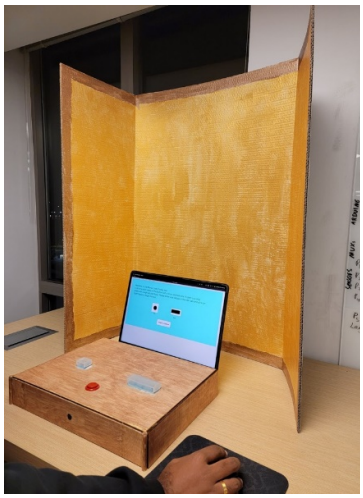


Fig. 18. 90% Complete Exhibit

MILESTONE 6 – CLIENT DEMO

For the sixth phase of the project, the final changes were made to the exhibit based on the recommendations received in the fifth milestone [Fig 20]. A demonstration video of setting up the exhibit, the user's perspective while using it, and packing it up into its transport configuration was made for this milestone. Lastly, the survey and collected data from the first-year showcase was examined to evaluate the project's performance and reflect upon it. This phase was essential to understand potential areas of improvement and recommend future changes to the project.

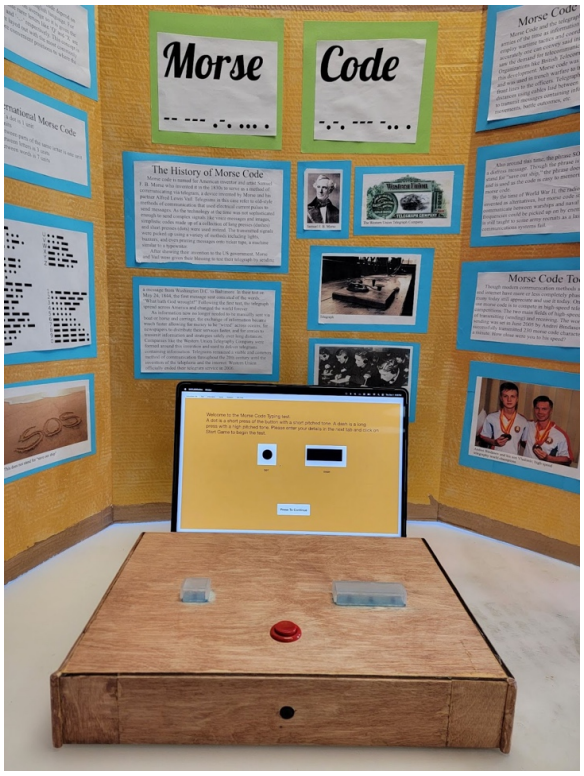


Fig. 20. Final Exhibit for the showcase

INDIVIDUAL CONTRIBUTIONS

My work throughout this project was mainly software based. Some of my responsibilities included maintaining the Gantt Chart, hours log, decision matrices, planning and designing the hardware, and creating drawings, models, and labelled images. However, my largest responsibility on this project has been sourcing, creating, and refining all the software used in the project. The Arduino code was an open-source code written by Vladimir Krsmanovic [9] and I modified it to include additional hardware components' integration. The flowcharts, MATLAB code including the back end in MATLAB and the front-end GUI in MATLAB App Designer was made by me. In addition to this, I edited and maintained the excel sheets for decision matrices and other quantitative evaluation tools. I would work with Danny and Zach during build days at FYELIC on the hardware as well. Furthermore, I reviewed the written content in memos and presentations and suggested changes during team meetings before submissions. As a member of a team of three, I believe that my work played an equally important role in the development, and especially the technical development of the exhibit.

ZACHARY USHER

1.7 INTRODUCTION

PROBLEM STATEMENT

The task assigned asked to design an educational exhibit targeted towards the middle school and high school demographic that fits the theme of espionage technology. Constraints for the exhibit include a size constraint of a 28 in by 36 in footprint when set up and it must fit in a 40 in by 30 in by 12 in box. The exhibit also must be able to be carried by no more than two individuals and setup and breakdown must take less than 30 minutes total to complete. The exhibit also includes a spending limit of $100 and a value limit of less than $1000. The difference between spending and value is that value also includes materials that team members already own, most notably laptops, circuitry, and other electronic elements that would far surpass the spending limit. Designs are also required to have an interactive component and an educational text component.

The existing problem implied by the task is that children lack the ability to meaningfully engage their interest in spy technology. While spy museums and media exist, museums dedicated to espionage are scarce and relatively inaccessible to many families. Spy media also often does not provide the same level of interactivity that museums do. Without easily accessible interactive learning opportunities, children may feel that the world of spy technology is closed off to them and will ultimately lose interest.

STAKEHOLDERS

The stakeholders of the exhibit include the first year College of Engineering program as they hosted the exhibition that will showcase all the museum exhibits as well as Professor O'Connell who oversaw the overall design process of these exhibits in the form of project milestones. The intended users, middle school and high school students are also stakeholders.

SCOPE

This report covers from the ideation and research stage of the design process up until the first completed prototype that was presented at the First Year Engineering project exhibition. The prototype is complete and ready to be displayed but not yet ready for commercialization as improvements can still be made.

1.8 BACKGROUND

History of the Problem

Children, by nature, are very curious. Anyone who remembers their childhood can attest that their friends or them fixated on random topics such as rocks, dinosaurs, trains, and many more. For children to engage their burgeoning curiosity, they need interactive resources such as museums, toys, movies, and books. While the internet has made information accessible to children, so long as parents have access to it, being able to engage their interests via touch, sound, smell, and even taste makes all the difference.

Research Summary

There is a vast existing market for spy toys and exhibits. Spy technology like invisible ink, secret codes, drones, and disguises fascinate kids as they are essentially magic that exists in the real world. Movies like the Spy Kids series and books like the Alex Rider series have engaged and will continue to engage children with the world of espionage for the foreseeable future. The Cars franchise even did a movie that parodied classic James Bond spy films. In terms of museum exhibits, by far the most popular museum dedicated purely to spies is the International Spy Museum in Washington D.C. [13]. The museum makes use of historical props and artifacts as well as interactive elements like movies, touch-and-feel exhibits, and games that "test your spy skills." While we, as a team of freshman engineers, have nowhere near the same number of resources, we can still take the core concept of an interactive exhibit and scale it down to fit into a transportable box.

Some critical aspects of exhibit design according to the Museum of Science in Boston as well as the Exhibit Design for Girls' Engagement (EDGE) Project [1] is to ensure that exhibits allow for social interaction and collaboration, are relatable to the kids, and must be accessible to children with wide ranges of ages and abilities. Museum exhibits should also grab their users' attention using a catchy title or flashy design; the exhibit should also be memorable and leave a lasting imprint on the user. One way to do this is to use a "wow factor" that is either a large spectacle or an element that makes the user feel accomplished. Some initial ideas of spy technology included one-way mirrors (the type commonly used in interrogation rooms), morse code, cryptography, radar, and a listening device. More advanced technology ideas such as stealth planes and vantablack paint were phased out due to price point or simplified to fit the constraints and resources available.

Additional research was done for the information to fill out the poster board. Much of the research about the history of Morse code was taken piecemeal from a variety of sources including History.com [14], Encyclopedia Britannica [15], and Techtarget.com [16]. Most information pulled from these sites were brief summaries of Samuel Morse's invention of Morse code along with the collaborative invention of the telegram and its spread throughout the United States and internationally. For the sections on wars and morse code in present day, research was conducted very similarly using websites that summarized historical events. Notably, a decent amount of research was put in to create write ups talking about ciphers and cybersecurity as modern versions of secret codes and stealing information, but these pages were ultimately cut as the poster had a limited amount of space and the team decision was to keep information more concise and directly related to Morse Code.

Ethical Concerns

As the topic of spy technology can include weapons and other devices that have historically been used in wars, it is critical that the project does not glorify war or violence. As the project is essentially displaying information publicly, it is important that said information is accurate and unbiased.

1.9 METHODOLOGY

Team Meeting Structure

Team meetings were overall conducted in an impromptu fashion where team members met depending on day-to-day availability. This was because schedules were relatively volatile depending on the workload for cornerstone and other classes. However, mentor meetings were scheduled at the set time of 6:00 pm weekly. on Mondays. While team meetings were seldom timed, they usually lasted up to 3 hours maximum and mentor meetings lasted anywhere from 60-90 minutes.

Research

Research was done individually with two sources, [EDGE] and [MOS] being prompted by Prof. O'Connell and the rest being found individually. From the research, we bullet pointed our major findings then listed out a few ideas for potential technologies. The research was conducted in two main areas: potential ideas for technologies and what makes for an effective exhibit. For more information about the research portion of the ideation process, see the research summary section above.

Priorities/Design Goals

The priorities and design goals were brainstormed at the mentor meeting and then weighed according to a rank order chart that was completed collaboratively. Portability and safety as design goals were determined by the given constraints while the other design goals, ease of creation, interactivity, and durability were decided based on team member preferences and our mentor's input. Portability can simply be defined as whether the design fits the size and weight requirements given as well as a subjective measurement of how easy or difficult it is to set up or carry. Safety is another must consider that users will be interacting with the exhibit physically as well as the fact that the target audience are minors. Ease of creation is a much more abstract goal that considers the cost and accessibility of materials as well as the amount of time needed to dedicate to building, coding, and research. Durability is also essential as the exhibit needs to last for a significant number of uses at the exhibition and beyond. The final and most abstract goal of the exhibit is interactivity. For an exhibit to be interactive it must be exciting enough to draw users in and leave a lasting impression on them.

When using a KTDA to order the design goals, we collectively decided that safety should be weighed the most due to the importance of preventing injuries amongst our young target user demographic. Interactivity was ranked second with the reason primarily being that the purpose of an exhibit is to make a lasting impact and allow for children to engage with information in a way they would not otherwise be able to. Durability was prioritized over ease of creation and portability as a heavier, more complex design would be favored if the complexity and weight enable it to sustain more uses over time. From this rank order chart, each of the design goals were assigned weights to be used in a KTDA Chart seen in table 7.

Topic Ideation

From the research process and discussion with our mentor, we decided on a final list of five topics then individually completed KTDA charts then averaged them together. The final list of topics consisted of radar, an enigma machine, a two-way mirror, cybersecurity, a Morse code game, and a listening machine. This final list was narrowed down from a longer list with ideas like vantablack paint and stealth bombers being phased out due to their predicted difficulty to create. These topics were then placed into three individual KTDA charts, one for each team member, with

	Ease of Creation	Portability	Interactivity	Durability	Safety	Total
Ease of Creation	-	0	-1	-1	-1	-3
Portability	0	-	-1	-0.5	-1	-2.5
Interactivity	1	1	•	0.5	0	2.5
Durability	1	0.5	-1	•	-1	-0.5
Safety	1	1	0	1	•	3

Table 7. KTDA Chart that was used to assign weights to each of the 5 design goals

	Ease of Creation	Portability	Interactivity	Durability	Safety	Total:	Weighted Total
Weight	2	3	9	6	10	•	•
Monkey Type	8	9	8	8	10	40	263
Number Memory	6	9	8	7	10	40	253
Type-racer	5	8	10	6	10	39	260
Piano tiles	4	9	10	5	10	40	255
Sequence Memory	7	8	7	6	10	38	237

Table 8. This KTDA chart shows the ranking of different Morse code ideas according to how well they fit the design goals.

each of the newly weighted design goals. The KTDA charts were then averaged with Morse code game being highest scoring by a marginal number of points.

Generating Ideas

From the KTDA, Morse code was decided as the final topic. Following this, we completed concept drawings and gave each other feedback and debated our ideas. Using the SCAMPER ideation technique, we first came up with simple, common games that could easily be adapted to accommodate Morse code. Examples of these include digit memory games, typing tests, and sequence memorization games. For the ideas we were most confident and interested in, we made a pseudo-concept drawing which consisted of a drawing and labels but without the descriptive paragraph underneath. The three concept drawings included a typing test, number sequence memory, and a method of two-way communication with Morse code.

Using the drawings and additional ideas, the ideas were ranked using a KTDA [Tab. 8] with each idea being measured up against the selected design goals with the corresponding weights. The typing test marginally won with consistently high scores for every design goal. The initial idea was to expand upon the type test to include different game modes in order to account for the close score.

Planning

Prior to the building process, we created a flowchart showing how users will interact with the app. The flowchart outlined a thirty second game that keeps track of the user's characters per minute and input accuracy.

We made CAD designs showing what early iterations of the model looked like. The design consisted of a simple box shape with dimensions chosen to fit over the keyboard of a 16-inch laptop. The box has circuitry and wires hidden inside with the button and buzzer components on the outside of the console. Additional Solidworks sketches [appendix C] showed the console on a regular size table with the attached laptop, keyboard, and mouse components.

Cardboard proof concept of console [appendix G] - the cardboard proof of concept showed the general idea and shape that the console would eventually take. The poster board was omitted from the CAD drawings and cardboard proof of concept as the shape was already assumed to be that of a typical tri-fold poster board.

Creation

The main proof of concept was that code could detect short and long presses. The code was borrowed from an online source listing their name as Vladimir Krsmanovic. The code, done in Arduino, used delays to detect and distinguish short and long presses as well as a manually coded translation of Morse code sequences into common ASCII characters. This code is attached to a simple LED, buzzer circuit where the LED and buzzer respond differently to the dot and dash inputs.

The first iteration of the console closely followed the cardboard prototype. We purchased wood from the bookstore then used AutoCAD sketches to direct FYELIC red vests in cutting the wood. The sketches showed basic rectangles except with holes to fit the button and buzzer. After acquiring the laser cut wood, the pieces were glued together using wood glue and held using clamps and dowels.

The programming began by using the outside source and transferring it over to MATLAB. MATLAB was preferred to Arduino in this project as the app designer in MATLAB allows for the creation of a user interface with elements such as text boxes and buttons being relatively easy to create when compared to Arduino. The interface consists of an instructions screen which prompts users to enter their name and age. They are then prompted to enter dots and dashes. From the instructions screen, the game then transitions into its main phase where it displays a letter and the respective Morse code awaiting the user's input. The interface displays the user's timer, beginning at 30 seconds as well as their accuracy which adjusts in real time to user inputs. Following either the user inputting all the letters or, more likely, the timer running out, the user will have their characters per minute and score displayed to them and a button to take them to the end screen which contains a QR code with a survey attached.

Data Collection Method

The data collection method was done in part using a Google Form survey attached to the end screen of the console. The Google Form [appendix D] uses questions asking for the user's feelings on the level of safety and engagement offered by the exhibit. Users are given options ranging from "strongly disagree" to "strongly agree" to gauge their level of satisfaction. Additional data on how much time each individual letter took, and the user's accuracy was collected in the code and transposed into table format in MATLAB.

Changes to Console

LEDs were added as a finishing touch to add a visual component to complement the buzzer as the auditory component. The holes for the LEDs were done using the help of red vests in FYELIC and experimenting with different hole sizes until the LED fit perfectly through one. wood finish and acrylics were applied as final aesthetic touches; the wood finish was acquired from a hardware store and drawn on while the acrylic was sourced from FYELIC and cut and glued using their services

Aesthetic Touches

Wood finish and acrylics were applied as final aesthetic touches; the wood finish was acquired from a hardware store and drawn on while the acrylic was sourced from FYELIC and cut and glued using their services.

Poster

The poster was created using a basic trifold that was then painted gold and bronze. Construction paper was used to outline the information boxes. Information and images in the boxes were researched online sources are listed below.

Individual Contributions

In terms of individual contributions, at the beginning stages of the design I helped lead the discussion of different ideas to help narrow down the wide range of ideas into the final five topic ideas that were present in the KTDA chart above. As I was the project manager for the first week, I was responsible for introducing our team to our mentor, Justin Bonapace, and for reading and compiling all the individual research into a presentation for the class. Since I had read over everyone's research, I had a solid idea of what the options were as well as the pros and cons of each. In the mentor meeting I did much of the typing for the KTDA charts.

I helped build the cardboard prototype, but my main responsibility while that was happening was creating the evaluation planning which included a table of all the design goals and how they could be measured [Appendix

D]. I separated the evaluation into two categories: team evaluations and test evaluations. For the team evaluations I created a team member stress survey to help evaluate the "Ease of Creation" design goal. I also created a first iteration of the final survey that would eventually become the QR code survey at the end of the final prototype.

Finally, I created the entire poster [Fig. 21] including buying the poster board and all the materials that were used including paint, construction paper, and printing paper. I did the research for all the information on the poster and wrote up and found images to accompany the text boxes. The research that went into creating the poster board is attached in the works cited.

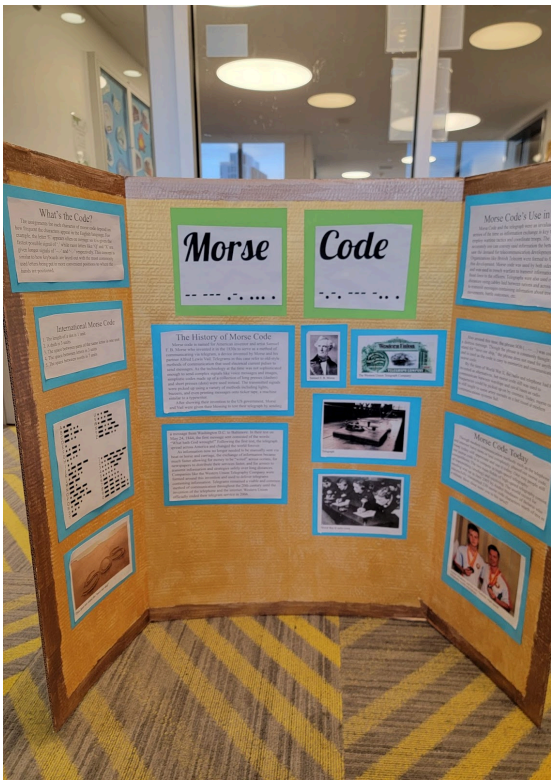


Figure 21. Final iteration of poster board.

1.10 FINAL DESIGN

PROGRAMMING/APP LOGIC

The code used for the project consisted of four main parts. Of these four parts, one part was implemented in Arduino using code found online [Appendix E]. The Arduino code was used for morse code inputs using a circuit and subsequent translation into words. Small hardware and logic changes were made to the code, written by Mr. Vladimir Krsmanovic, to meet the objectives and desired goals of this project. We would like to take this opportunity to thank Mr. Krsmanovic since morse code translation and serial outputs have been the backbone of our project [9].

The other three parts that were used in the project were made in MATLAB and, in one of the cases, the MATLAB App Designer. The other three parts included the app [Appendix E], the main keyer and translator function [Appendix E], and the trial [Appendix E]. M6.mlapp was used for the User Interface and the main Front-End parts of the software. MorseKeyerTrial2.m was used for the trial tab to make the user input the elementary characters before beginning with the game. MorseKeyer7.m was the backbone of the app and had most of the logic built into it. MorseKeyer7.m was responsible for inputs, translation, changes in the UI, as well as data collection. Both MorseKeyerTrial2.m and MorseKeyer7.m formed the back end of the application.

CONSOLE

The “console” is the physical component of the exhibit that goes over the portable laptop. Its main function is housing all the electronics, but also prevents access to the keyboard since it covers the integrated keyboard on the laptop. It is made up of laser cut wood glued together with wood glue and closely resembles a box, however the back and bottom are not enclosed off [Fig. 22].

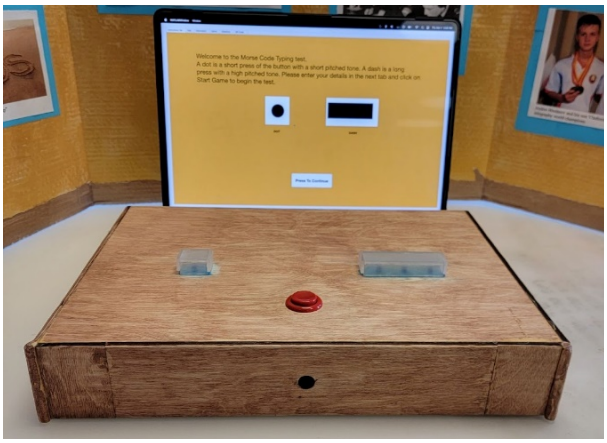


Figure 22. Functional component of the exhibit

As seen in figure 22, the console also contains the electronic components that will interact with the user. This includes a piezoelectric buzzer 4 LED lights that are covered by acrylic boxes and an arcade button [Appendix I], The LED lights are separated so that the single LED on the light signifies a “dot” and three LEDs on the right signifies a “dash”. The whole outside of the console is applied a wood finish.

Underneath the console lays all the circuitry for the button, LEDs, and buzzer to function. As seen in figure 24, The buzzer and LEDs are connected to a button. In this diagram the arcade button is represented by a push button and in the real example the button is not on the breadboard but protrudes to the outer surface of the console so that the user can interact with it. Therefore, if the user presses the button, the LEDs will light up and the buzzer will buzz.

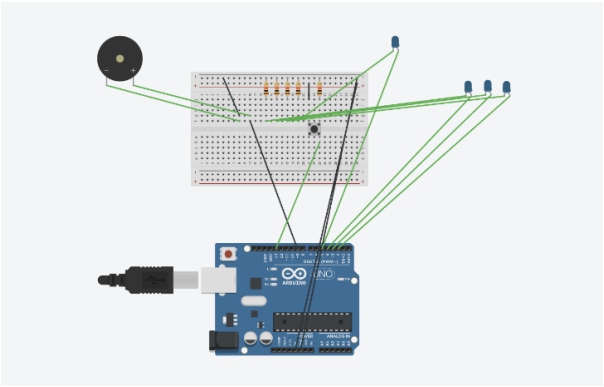


Figure 24. Final wire diagram of the electronic components.

In addition to covering the keyboard of the laptop, it also hides the wiring that was conducted underneath the console. This is done by taping all the wires to the back of the console and tucking any lose wires in during setup [Fig. 23].

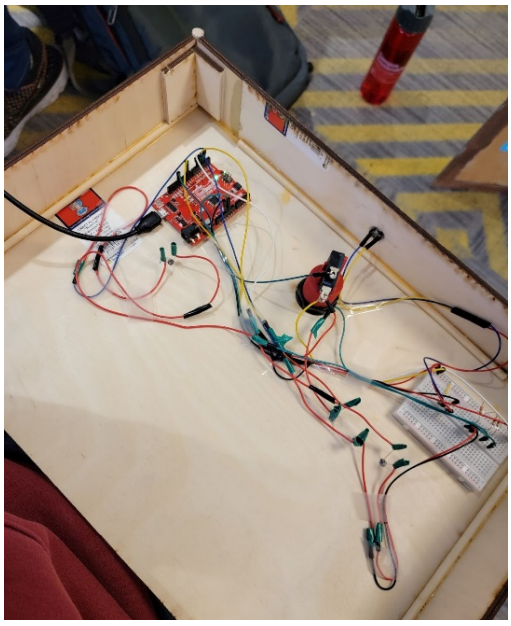


Figure 23. Electronics and wiring underneath the console.

Educational Element

The educational element of the exhibit is a tri-fold poster board containing various information related to Morse code [Fig. 26]. The poster is painted gold with bronze lining to match the rustic aesthetic of the telegrams Morse code was created for. The sheen of the paint also comes with the bonus of attracting users’ attention. In the middle of the poster, right above the console is a paragraph explaining how Morse code was invented and how it was used practically in tandem with telegrams. The left fold of the poster details the rules of international Morse code, this section doubles as a secondary pair of instructions for the user. The right side of the poster discusses how Morse code was used practically in World Wars I and II by governments in order to provide a more exciting application and to tie the exhibit back to its intended theme of spy technology. The bottom right corner explains how Morse code is still used today in high-speed telegraphy

competitions. Images with captions also accompany corresponding information in the text.

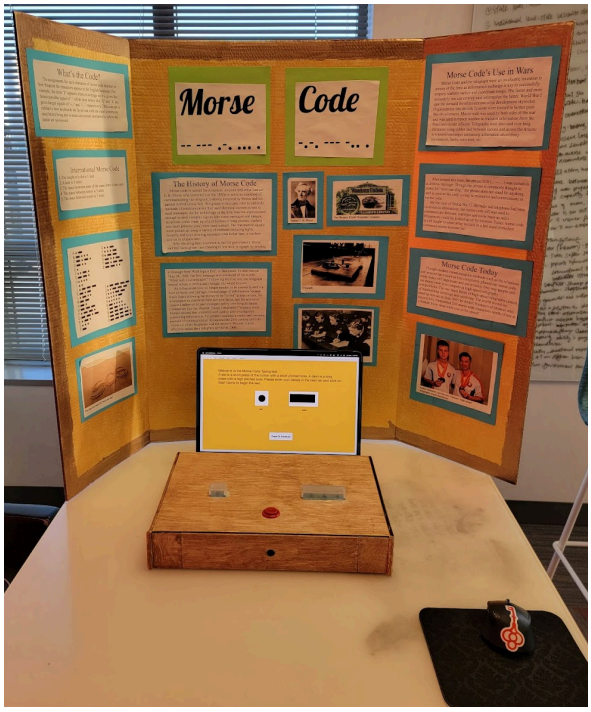


Figure 26. Morse code exhibit fully setup

User Experience

The user will walk up to the exhibit and read the introductory tab that explains how the program will work [Appendix G]. After clicking the button to continue, the program will prompt the user to input a “dot” by tapping the button for a short period of time and if the user inputs it incorrectly it will not proceed. This process is the same with the dash input, but the user must hold the button for a set amount of time [Fig. 25].

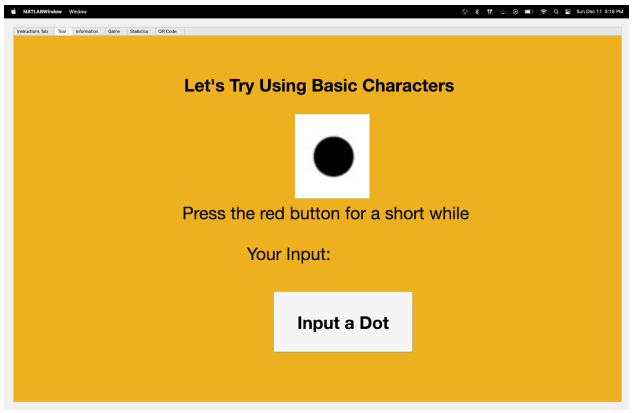


Figure 25. The "tutorial" tab of the app that guides the user on how to input a "dot" or "dash".

The app will then prompt the user too input their age and grade that MATLAB will record [Appendix G]. The game will start when the button is pressed. The user will have 30 seconds to input as many Morse code characters as they can. If the user inputs the wrong series of dash and dots, then the program will mark that character as incorrect and move on to the next character [Fig. 27].

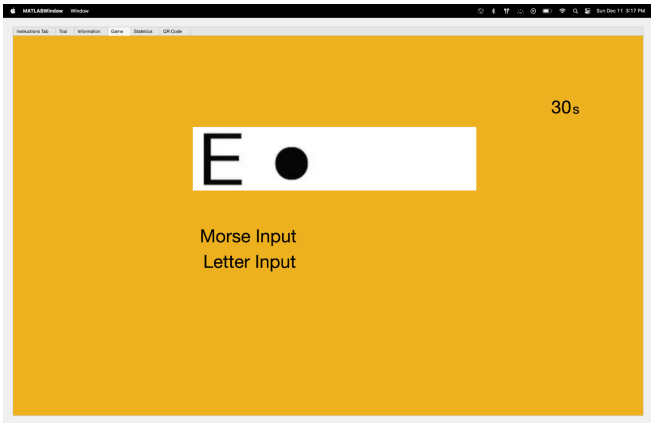


Figure 27. The "game" tab with the character displayed and how to input the character. In addition, the inputted character by the user is displayed.

Afterwards, the user will see the statistics of their performance. This includes their accuracy of getting the characters correct and their characters per minute [Fig. 29].

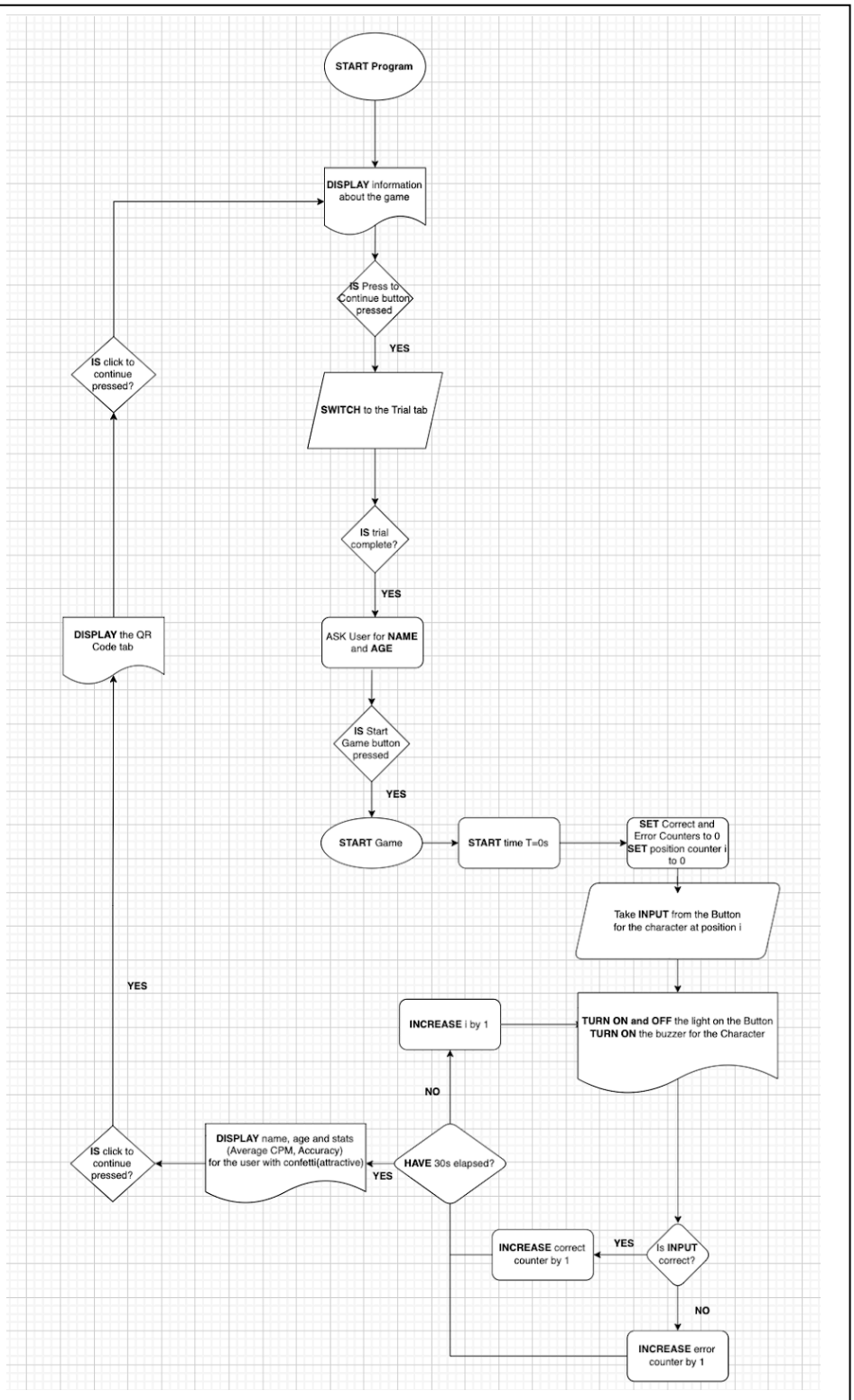


Figure 28. Flowchart for app interactivity

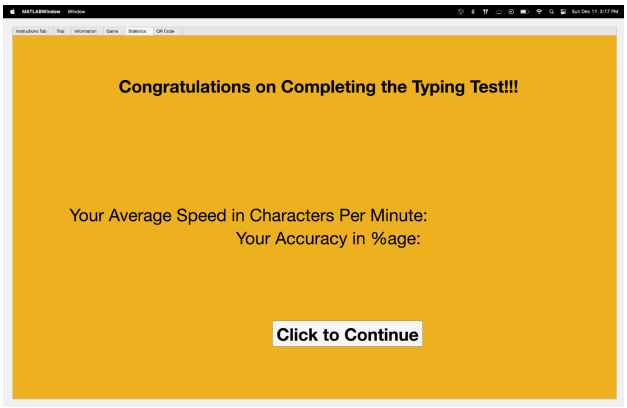


Figure 29. The statistics tab of the app that shows the user their characters per min and accuracy.

Then, the user is prompt to a QR code that houses a google form that collects feedback. The user will scan the QR code and fill out the questionnaire. See figure 28 for a graphical representation of the user process.

1.11 RESULTS

AUTOMATIC DATA RESULTS

For the automatic data collection aspect of this project, the MorseKeyer7 function took individual letter inputs for each user and stored them in a table which would be appended to a local CSV (comma-separated values) file [Appendix D]. The data that was collected included 6 columns in a table which recorded the age, grade, correct letter input, letter inputted for the input, and time taken to input the letter. Another column included in the six columns is an encoded number which indicates if the letter inputted is correct (0) or wrong (1).

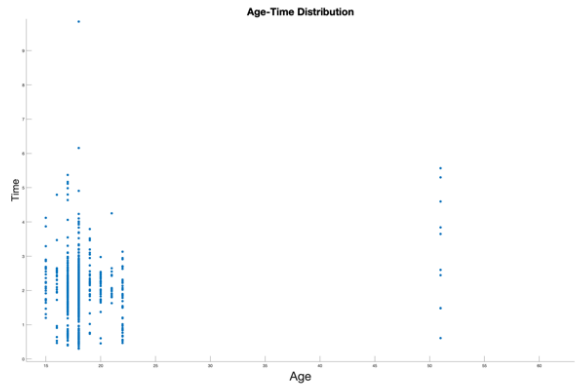


Figure 32. Age-Time Distribution scatter plot

To visually interpret the data with 1,073 individual letter inputs, MATLAB was used to plot histograms and scatterplots [Fig. 32]. The age of the users who used the exhibit ranged from 15 years to 51 years. A scatterplot plotted between the age of the user and the time taken to input every letter by the user shows that in general, with an increase in age, the time taken to input each individual letter increases with little to no difference seen in the times for users between the age group of 15-25. The general trend in collected data shows that all the users of the exhibit were in ages between 15 and 25 years with only one user aged 51 years old.

A histogram of the unfiltered data, which included errors, for the frequency and time taken to enter the data shows a bimodal normal curve [Fig. 31]. One of the modes which shows a lower frequency and time indicates that errors were easy to make and took less time, implying that users took lesser time to make errors. The second mode with a greater frequency and time indicates that the mode of the correct inputs is around 2s. Which means that most of the users took approximately 2s to input a letter using Morse

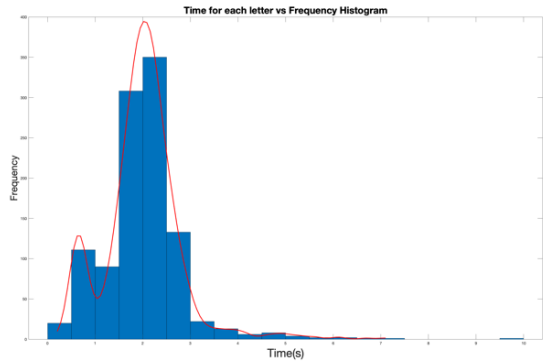


Figure 31. Unfiltered histogram for time that each letter took to be inputted

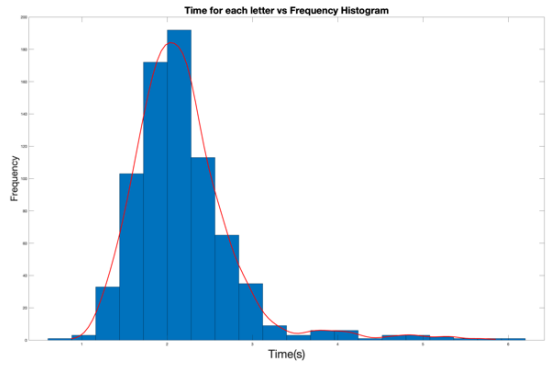


Figure 30. Filtered histogram for time that each letter took to be inputted

code. The same trends seen in are seen for the filtered data histogram with the mode at around 2s [Fig. 30].

Google Form Results

The results of the survey were overwhelmingly positive with 94.12% of users responding “agree” or “strongly agree” when asked if they felt engaged by the exhibit. Of the 94.12%, 25% of users selected “agree” with the remaining 75% selecting “strongly agree. Only a single user left a negative response [Fig. 33]. When asked if they felt the exhibit was safe, 100% of users selected “strongly agree.” Some of the written feedback suggestions received included making the exhibit more difficult, adding a tutorial for letters, making it so inputs do not carry over to the next letter, and making the exhibit cover words instead of just letters.

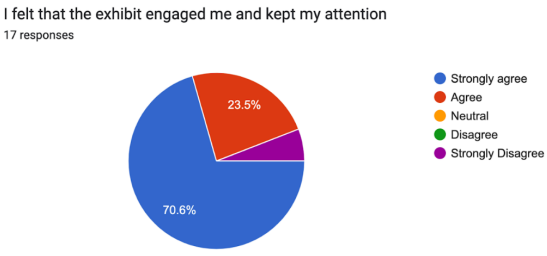


Fig. 33. Pie chart of the responses to the question "I felt that the exhibit engaged me and kept my attention"

Observational Data

During the First Year Engineering Project Expo, observational notes were taken and observed by Danny Liu who stayed at the exhibit for much of the time [Appendix D]. It was noted that some users were competing with their friends to see who would get the higher character per minute score. As a result of this interaction, many of them replayed the exhibit to better their scores. It is also

observed that there were more people in the beginning of the expo at the exhibit then the end. Some users were confused or didn’t understand how long to hold the dash input. Some users breezed through the data collection tab or put information that was evidently not true. Overall, some users commented that the exhibit was “really cool”.

DANNY LIU

1.12 DISCUSSION/ANALYSIS

It is suitable to first draw a clear distinction between the stakeholders of this project and subsequently expand on their perception and point of view on what priorities are valued to them. Therefore, identifying and taking into consideration the point of views of stakeholders is what defines if the project was successful or not.

Firstly, the client put an emphasis on their constraints for the project. The constraints were mainly size requirements. This included the footprint of the setup, the transport limitations, and budget restrictions. Many of these constraints were mostly meet. The exhibit only takes about half of the plastic bin [Fig. 34]. Therefore, making it easy to carry around site to site. In addition, the exhibit is overvalued, however it is discussed in the recommendations that the laptop can be easily replaced with a cheaper laptop or a monitor and raspberry pi [Appendix I]. The expensive laptop was utilized because testing and prototyping was used on that laptop. Therefore, with those small changes the exhibit meets the value requirements of under 1000 dollars.

At the first-year engineering showcase, 69 people tried the Morse Code exhibit within 90 minutes. Also, it was noted through the observational data that some of those people played the game twice to improve their score. As discussed in the methodology, the group agreed that an interactive exhibit would result in the user attempting to replay the game. In addition, based on the data that we collected at the First-Year Expo through a Google form, all the 17 individuals who responded to the survey felt that the exhibit was safe to use and 16 of the 17 respondents replied agree or strongly agree that the exhibit was engaging [Fig. 33]. The one respondent who put strongly disagree also included a positive comment. Therefore, that datapoint is ambiguous and was not strongly considered to be part of the data set.

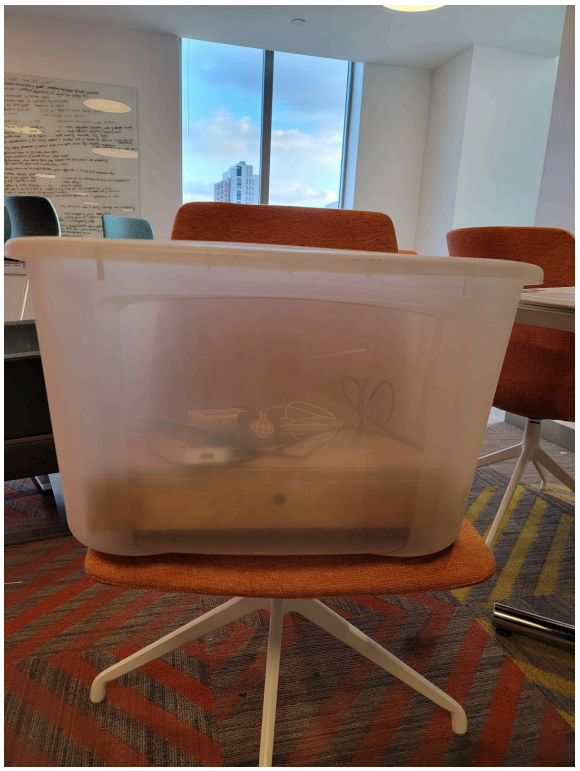


Fig. 34. Transport configuration of the final exhibit

Overall, the exhibit proves to successful because 94 percent of Google form respondents stated that they felt that exhibit was engaging, and 100 percent felt that it was safe to use [Fig. 33]. In addition, some people replayed the exhibit, which is what the team was looking for to deem the exhibit successful. However, the exhibit could be improved significantly given more testing and software refinements. Some users experience “chained incorrect inputs”, where the user was too slow to input a character and then the program will go on too quickly and mark 3 or 4 characters as incorrect. During all these trials, it was only once that a member had to intervene to restart the app due to a glitch that we had not faced during testing.

1.13 CONCLUSION

Overall, the final prototype exhibit has met all the required constraints of size and portability because it fits compactly in the travel bin that was provided and the setup time is well under five minutes. It also met certain design goals set by the Team and our educational stakeholders (refer to stakeholders discussion). This includes the ability to utilize the MATLAB design app as our main app interface and the ability to autonomously collect data.

The exhibits interactivity performance also met the Team's expectations and goals because of the generally positive feedback we received from our google forms [Appendix D] but also the amount of data points we were able to collect. In addition, through some observational data, signs of a good interactive exhibit like users replaying the typing game were observed and some users also challenged their peers to beat their scores at the end of the test. Overall, the interactivity of the functional component met the Team's goal.

However, one note and challenge the Team faced was to connect the functional component to the passive educational component (the poster board). Throughout observational studies, many users didn't bother to read or look at the poster. They mainly focused on our game.

1.14 RECOMMENDATIONS

Although we believe that the exhibit was overall successful, there many scraped ideas that could have gone into the exhibit because of time and resource constraints. In addition, due to observational data, recommendations to improve the passive educational element of the element is also needed before moving on to the final product. There are also hiccups to certain design elements that could have been more refined or planned in the beginning of the process that would have made the exhibit much better.

SCRAPPED IDEAS

In the beginning, the Team's vision is to create a suite of Morse code games like the typing test so that users can have different ways to learn Morse code. This includes ideas of having a type racer station, sequencing memory different Morse code combinations, and even a memorization game. There could be multiple computers and consoles that run each type of game or have a single computer have them all in library and the user can choose which one to play.

Two aesthetic considerations were to 3D print the Morse code telegraph to act as the button. So instead of the plain arcade button, the user can use a functional Morse code telegram to input their dots and dashes. The second consideration was to have a high score screen in beginning, which may incentivize users to try to beat the high score. However, we could not implement this feature due to time constraints.

PASSIVE EDUCATIONAL ELEMENT

As noted in the Discussion and Conclusion tabs, the poster did not meet the Team's goal of interactivity because not many users really looked at. This could be remedied by connecting the app to the poster board in some way. One idea could be to have LED strips on each written component of the poster and when a user finishes the typing test a random part of the poster could lit up and direct a user's eyes towards.

REFINEMENTS

Some aspects of the console could be upgraded to create a better immersed experience. One such change would be to get bigger planks of wood because we had to cut the front of the console into three pieces to create one long piece because the size of the wood was too small to create it in one piece. In addition, we noticed during initial testing that the LEDs are much too weak to disperse in the acrylic box. Therefore, replacing them with brighter LEDs will prove to make the exhibit pop out more. Also, implementing a louder buzzer would greatly improve the immersiveness of the exhibit since it was the room was too noisy for the buzzer to effective. One strategy could be to use MATLAB's integrated computer sound commands to play the sounds since the speakers on a laptop would be much more powerful than a piezoelectric buzzer.

Finally, since the laptop being used at the exhibit is much more than the allowed value, it is appropriate that the laptop can be replaced with any cheap laptop that can cost 300 dollars. Another option is to use a small monitor and a raspberry pi to run MATLAB and it would act very similarly to our final prototype setup.

1.15 LESSONS LEARNED

CONTRIBUTIONS

I mainly worked on the physical components of the project. That includes working on the console and all the wiring decisions and finalizations. Through the end of the project, I installed the LEDs to the console and wired them up accordingly. Due to needing to have the LEDs at specific places, I had to extend a lot of wires by stripping wires and wrapping them in electrical tape [figure # in appendix]. In addition, for important connections like the wires to the LEDs, I soldered them to make sure they won't fall out or be poorly connected.

I also compiled much of the materials that are needed for each milestone memos and write portions of what is needed for them.

RESOURCES

This project had so many moving parts and resources that we need having just a list of things that the group needs was super helpful. For example, listing that we have a lot of the electronic components already provided by FYELIC or Professor O'Connell greatly decreased the costs the group spent [refer to bill of materials in appendix]. As a result, our Team has met the maximum budget requirement and only spent around 69 dollars in materials. Of the 69 dollars, I contributed around 20 dollars to buy wood from the Northeastern University bookstore and that was instrumental to the making our console.

In addition to material resources, I have taken a lot of time into the creation of this project. I spent around 60 hours in total since the project started working on the various components that was needed for the exhibit to be successful [refer to hours log in appendix]. However, I realized that much of my working style is in bursts rather than consistent work times that may clash with my project member's styles. To compensate, I have these burst a bit earlier before deadlines. This approach has worked so far, and it is something that I will incorporate in feature endeavors.

Coming into the project, I didn't realize how important it was to keep track of the various resources my team has. It really clears up what work needs to be done with resources like Gantt chart [refer to Gantt chart in appendix]. It is also easier to communicate what work needs to be divided up and their respective due dates, so you don't hinder the progress of the group. Therefore, in future works making these resource tracking strategies can create a productive workspace.

REFLECTIONS ON LEARNING

What I really learned about this project is the amount of stuff I really don't know. So much of the work we did as a team was teaching ourselves things that weren't specifically taught in class. So, I think other than learning like technical aspects like wiring, coding, or even building and using FYELIC resources is how to get information and how to use that information. That is the main takeaway from the work I've done on this project, and it is something that will carry on to my future works. Outreaching and asking for help is something that I've always struggled with, and I have really developed that this semester.

REFLECTIONS ON WORKING IN A TEAM

Working as a Team at the beginning of the semester was undoubtedly very difficult for me because I didn't know what any of my group member's work styles were. There were times in the beginning when we crammed memos the night it was due. However, as we got to know each other and how we like to work, we started to make

accommodations like keeping our weekends free because we value our breaks between milestones.

As a result, we broke down the work between each group member base of what they were good at. For example, I did the writing portions of the memo because I was relatively skilled in writing while my other team members take the tasks of resource management or keeping the design notebook updated. Since I was compiling most of the milestones, I took the role of the project manager in a way by giving my team members their division of the work and holding meetings to discuss what needed to be done and making sure it was done by the due date. I also like to get things done relatively early, so I don't have to worry too much about the due date. Therefore, I pushed my team members a lot to finish work before deadlines and that has really helped the Team in general because we understand that we all have obligations too. Despite a lot of misunderstanding in the beginning, my group faced the challenges with an open mind and understood where each member was coming from. Therefore, we made a lot of compromises and set how we work as a team as described above.

The second biggest thing I learned from this project is how to work with people. I believe it is super important to understand how your project members work and keep an open mind when mediating conflict [can reference team contract]. There were times where there are some frictions because we didn't manage our time as a group effectively. Conflict mediation strategies and overall communication strategies is one of the biggest takeaways and is something I will apply in my future because engineers rarely work alone.

ARYAN KALASKAR

1.16 DISCUSSION AND ANALYSIS

To begin with the discussion of the project, it would be suitable to first draw a clear distinction between the stakeholders of this project and subsequently expand on their perception and point of view. One of the most important things engineers need to do is identifying and taking into consideration the point of views of stakeholders of any project.

Firstly, the client's objectives were met through this project while the constraints were not violated. The constraints were mainly size requirements, which expanded on the footprint of the set up and the transport limitations, and budget restrictions, which capped the cost at which the project could be executed. Based on the data that we collected at the First-Year Expo through a Google form [Appendix D], all the 17 individuals who responded to the survey felt that the exhibit was safe to use and 16 of the 17 respondents felt that the exhibit was engaging.

From the users' perspective, however, the exhibit could be improved significantly given more testing and software refinements. At the first-year engineering showcase, 69 people tried the Morse Code exhibit within 90 minutes [Appendix D]. This along with an estimated turnaround time of one minute implies that there were approximately 46 users trying our exhibit every hour. This figure includes the users who played the game more than once as well, however, it is worth noting that the attempt to gamify the concept to make it a fun exhibit idea was successful. During all these trials, it was only once that a member had to intervene to restart the app due to a glitch that we had not faced during testing. Thus, apart from the exhibit's overall aesthetic appeal, it is safe to say that the users were able to find the exhibit interesting.

1.17 CONCLUSION

Overall, the final exhibit was able to meet all the client's objectives and almost all design goals. Starting off with the constraints, the size dimensions were within the constraints of a maximum footprint of 30in by 36in when set up and sized to fit in 40in by 30 in by 12in tote bag or box in the closed configuration. Additionally, the project costed the team less than $100 and the value of the project could be kept under $1,000 as outlined in the budget constraints.

As for the performance of the exhibit, the project was able to meet design goals effectively. Safety, durability, and interactivity were some of the main design goals the team had in mind while working on the project and the sheer number of users who used this exhibit within the short amount of time and its continuous transportation are testimonies to its performance according to these goals. One of the aspects of our problem statements was the implementation of an automatic data collection system and the final iteration of the software was effectively able to do so and recorded 1073 letter inputs in a spreadsheet during the showcase.

1.18 RECOMMENDATIONS

While the project excelled in most of the aspects, it had some shortcomings too, most of which pertained to its aesthetics and the user experience. One of the shortcomings of the project pertains to the GUI, which was not as attractive as it could have been. Another shortcoming of the project was in the overall exhibit including the posterboard and exhibit space, which were not able to grab the attention of the users as they came to our station.

While the project could be considered a success given that it met most of the objectives, goals, and all the constraints, there are many ways in which the project could have been better than what it is at this stage. Some of the ways in which the project could have been improved are:

3D Printed Keyer

One of the ideas that were considered but never implemented was the inclusion of a 3D printed Telegraph Straight Key, just like the ones used historically to communicate in Morse Code. As seen in image/figure [include image number], a key would have made the morse code exhibit more aesthetically intriguing.

Use Of Brighter RGB LEDs

The implementation of LED lights into the console to indicate a dot input and a dash input separately was a last-minute change made to the console and was ill-planned. The changes included connecting standard LED lights to the console with a 'frosted' acrylic cover on top of them to scatter the light. However, after seeing the Finery of Sphinxes' memory game project, in which they used much brighter RGB LED lights, we realized that we should have planned the changes in advance and considered different options before making modifications to the console. The use of brighter RGB LED lights is something that we can implement in future iterations of this project.

Software and Hardware Changes

While the software back end was free of glitches except one instance and the data collection was successful, the overall aesthetics of the GUI could be much better than what it is currently. Some ways in which it could be improved is better color schemes, backgrounds, and a smoother flow between tabs and the game.

Another change that would be recommended would be an improved algorithm for data collection. The current algorithm for collecting data was not the most efficient, however, considering the small sizes of the csv and spreadsheet files, this algorithm proved to work well. The usefulness of the data collection can be expanded upon after importing, cleaning, and visually understanding the 1073 letter inputs that were recorded during the first-year engineering showcase.

As for the hardware, the computer can be replaced with a raspberry pi and monitor. This would reduce the cost of the project significantly. In the current version of the exhibit, a 16-inch MacBook pro was being used, however, a cheaper laptop with at least 16 GB RAM could replace the MacBook easily if the raspberry pi and monitor system is not viable. Additionally, using the computer speakers and MATLAB to play sounds would improve the exhibit since the computer speakers are louder than a piezo buzzer, however the lead and lag associated with the multiple hardware and software bridges has not been evaluated yet.

1.19 LESSONS LEARNED

CONTRIBUTIONS

My work throughout this project was mainly software based. Some of my responsibilities included maintaining the Gantt Chart, hours log, decision matrices, planning and designing the hardware, and creating drawings, models, and labelled images. However, my largest responsibility on this project has been sourcing, creating, and refining all the software used in the project. The Arduino code was an open-source code written by Vladimir Krsmanovic [citation required] and I modified it to include additional hardware components' integration. The flowcharts, MATLAB code including the back end in MATLAB and the front-end GUI in MATLAB App Designer was made by me. In addition to this, I edited and maintained the excel sheets for decision matrices and other quantitative evaluation tools. I would work with Danny and Zach during build days at FYELIC on the hardware as well. Furthermore, I reviewed the written content in memos and presentations and suggested changes during team meetings before submissions. As a member of a team of three, I believe that my work played an equally important role in the development, and especially the technical development of the exhibit.

RESOURCES

As a part of this project, I realized how important managing resources in a team is. Keeping a log of everything that goes into the project right from the smallest pieces of hardware to larger components to even the time that every member has put in has helped me evaluate and understand our limits better. Furthermore, resource tracking was extremely useful in making the planning and decision making more systematics, without which a log of the parts used, and the budget tracking would be all over the place.

As for the Gantt Chart, I initially did not understand its significance, however, as the complex phases of the project came up, I was able to understand how important it was to plan of time and set clear goals to ensure smooth operations.

Working in tandem with a resource management spreadsheet was a great learning experience and I look forward to using such tools in the future in my career.

As listed in the bill of materials in Appendix I, I gave my laptop to be used as the display for the exhibit. Additionally, some of the wires from my Spark Fun Kit were used in the wiring for the console.

REFLECTIONS ON LEARNING

This project was a great learning experience in many aspects. Firstly, it was the first time I had to use MATLAB and its app designer, something that I hadn't used much outside of class to build a whole functioning app that would be used by children. Additionally, the integration between software and hardware was something that I had to teach myself a lot about through research and with the help of Prof. O'Connell. This was my first time working with csv files and I can confidently say that this experience and the learning it entailed significantly changed the way I visualize and work with data.

For the more non-technical aspect of my learning, I was able to manage my time more effectively and spread the work over a few days to reduce the workload. Consistently learning about the software and systematically working on it to an extent where any changes to be implemented would require minute changes and would take not more than 30 minutes made me feel that I succeeded in

improving my technical and non-technical skills to a great extent. I believe that I can carry forward these learnings into my career as well.

Reflections on Working in a Team

After working on Team Chimera, I was able to understand delegating the work more efficiently based on the individual strengths. One of the aspects of understanding the team members during the first few weeks of the first project was understanding everyone's strength and interest. I, for example, did all the coding and software-based work since I thought of it as my strength and something I brought to the table. Furthermore, as we worked on the projects together, I realized that efficient communication and follow-ups are essential elements of any team-based project. This was evident through the fact that there were days when either Danny, Zach, or even I could not join the discussions due to other engagements. However, what kept us going through this was the coordination and individual follow ups. A method we used to delegate the work during this process was using individual to do lists and sharing them with everyone on the group chat. This was especially helpful because we would remind each other of the progress and things left to do.

Secondly, through this project, I was able to become more empathetic towards everyone's situation and was able to cover for them at times. Understanding that everyone is a first-year engineering student who has lectures and work from 4 classes each including 2 cornerstone classes was something that took some time initially. However, after I started being more understanding towards my team members, I was able to work more effectively and try and help them with their work for the project as well. This was especially helpful during build days when only two of the team members, sometimes including me, would work on the project at FYELIC.

ZACHARY USHER

1.20 DISCUSSION/ANALYSIS

Overall, I felt that the exhibit was a success. The exhibit clearly passed the constraints as it easily fit inside the box and could be carried easily by a single person. The spending limit was not overtaken, and the value was kept under $1000.

As someone who worked predominantly on the poster board, I knew and understood that the information on the poster would be heavily overshadowed by the console. However, I was still disappointed to see that the poster was largely ignored by the users. This may have been because people were pressed for time at the exhibition and needed to go see as many exhibits as possible but calling more attention to the poster will be considered in future iterations of the exhibit.

As for the console, the survey showed that 100% of respondents felt that the exhibit was safe. This conclusion was further supported by the fact that, in all the field tests and exhibition, no injuries were sustained by the users. Additionally, out of the 17 total survey responses, 16/17 respondents selected ‘agree’ or ‘strongly agree’ that the exhibit was engaging. Strangely, the single person who selected ‘strongly disagree’ left positive verbal feedback contradicting the negative response. One positive observation was that users were using the game to compete with their friends to engage with the experiment. Some criticism included users responding that they felt the game was too easy as well as that there was an initial input delay. The input delay is likely due to the objects being created in the MATLAB app and the difficulty could be altered by adding or reducing the time in future iterations.

1.21 CONCLUSION

The final prototype certainly met the constraints as the exhibit was compact, easily portable, and, when set up, was well within the size constraint. As for other design goals, most users answered that they felt the design was safe, and there were no injuries sustained during any of the tests or the exhibition. Most users felt that the exhibit was engaging as shown by the survey results with one person answering that they disagreed but still giving positive feedback in the open-ended writing section.

One concern of the team is that the poster board as an educational element was not being effectively utilized by people coming to the exhibit. While this can somewhat be explained by the chaotic nature of the exhibition and the fact that people had a set amount of time to observe and engage with many different exhibits, more could have been done to tie in the poster board content to the interactive element. Another problem faced was that the project consisted of only one game mode instead of the planned two to three due to coding and building taking longer than the expected amount of time. Problems and concerns aside, the exhibit overall made a positive impact giving the users a chance to learn and enjoy Morse code through friendly competition and active learning.

1.22 RECOMMENDATIONS

Over the course of the design process, we noticed a few flaws and imperfections in our design that we simply did not have the time or resources to address. Additionally, we scrapped some ideas that we thought would overall be beneficial to the project in order to meet the time constraint.

SCRAPPED IDEAS

At the ideation stage, the initial plan was to create a game with different modes and stages all relating to Morse code. We took inspiration from the site, Human Benchmark which has a wide variety of memory games along with a typing test. We were planning to create a digit memory game along with a short word memory game. These were ultimately scrapped due to time constraints and how difficult these activities would be for new Morse code users.

Two aesthetic considerations were to 3D print the Morse code telegraph to act as the button. So instead of the plain arcade button, the user can use a functional Morse code telegram to input their dots and dashes. The second consideration was to have a high score screen in the beginning, which may incentivize users to try to beat the high score as well as showing the high scores of professionals who compete in high-speed telegraphy.

REFINEMENTS

The poster could have been more eye-catching with the addition of LEDs framing the information boxes. Another way to make the poster board more appealing would be to have the console and poster board cross reference each other. For example, the ending screen displaying the user's accuracy and characters per minute could also reference the high score of Andrei Bindasov's 230 characters per minute mentioned on the poster board. A scoreboard would also have further enhanced the competitive, arcade nature of the game. The poster could also be further accommodated to fit the needs of people with sight disabilities by utilizing voice over readings of the information. Similarly, the console could utilize voice over instructions to make the game more accessible.

Another flaw in the final design is that the LEDs used on the console were too dim and did not light up the acrylic leaving them relatively unhelpful for the users and useless overall. Using brighter LEDs would add another visual component not only making the console more likely to draw attention but also make the console more accessible to the hard of hearing who are not taking advantage of the different pitches made by the buzzer. The code for the console could also be adapted such that the delay before inputs is allowed is shortened or extra time is given for the objects in the app designer to load before the game starts.

1.23 LESSONS LEARNED

CONTRIBUTIONS

Besides working on the memos, I did all the poster board research, writing, and construction. While I was there to help with the building, my teammates did most of the circuitry and construction of the console itself. The poster was painted gold with bronze accents in order to match the rustic aesthetic of telegrams. Information from the poster was gathered from a variety of sources [see works cited in appendix] and covered a wide variety of topics including the history of Morse code, its applications in wartime settings, and modern applications. The poster went through two main iterations with the second one having the amount of information scaled down with parts related to cybersecurity being removed in order to present the information most relevant to the exhibit concisely. The second iteration also had information moved up as to not be covered up by the console when in display configuration [see display configuration in appendix].

RESOURCES

The project had a $100 spending limit of which $69 total were spent. Most of the expensive parts including the computer and the circuitry were already owned and a significant portion of the resources were sourced from FYELIC (see appendix). I purchased the poster board, paint, and wood finish from a local hardware store.

Besides the physical resources, another critical resource was time spent on the project. This project took up a large portion of my spare time [see hours log in appendix]. Budgeting time, scheduling meetings, and divvying up work based on our individual skill sets were critical to effectively manage our time. Additionally, we found that the most efficient way of working was to work in the same location. Even when we were doing different and unrelated tasks, it was helpful to bounce ideas off each other and be able to offer help. As we became more familiar with each other's working styles and skill sets, we sped up the process of dividing up work significantly, having Aryan do most of the coding, Danny most of the building, and I was left primarily with the research and writing portions of the project.

REFLECTIONS ON LEARNING

As someone who, prior to cornerstone, had little experience with the engineering design process, going through both projects 1 and 2 taught me a lot about how to effectively apply the process to problems. Especially when given open ended problems, I found that it was easy to get lost in the ideation process. Using processes like SCAMPER to ideate then using concrete decision matrices to decide on an idea streamlined the early stages of the EDP significantly. Going forward, I will continue to use these strategies to break down open-ended projects into collections of more manageable tasks. Along with learning how to use the EDP, I learned some more general information about cybersecurity from my background research that ultimately did not end up making the final cut.

REFLECTIONS ON WORKING IN A TEAM

Due to our group having only 3 members, I took up the responsibility of being project manager for both milestones one and four. As project manager for milestone one, I initially felt overwhelmed as I had other responsibilities including a midterm that week. My responsibilities as project manager for that week included writing an introduction email, presenting our work for the milestone, and writing and submitting the memorandum. One of my main takeaways being the first project manager was that I should have taken charge and set a strict due date as to not have everybody turning in their work near midnight of the

day the project was due. By the time of milestone four, I had learned my lesson and much of the stress I felt as project manager for milestone one was alleviated as each team member had their work done at a reasonable time. I think that my presentation skills also significantly improved in my second round as project manager; I was able to control my nerves a lot more thus letting me crack a few jokes and let my personality shine through in the presentation.

At the beginning of the semester when we were assigned teams, I initially was upset that these teams were for the entire semester as I wanted to meet and work with a wide variety of different people. Now, having been through both projects, I know that the reason why these teams were made early was to build up our synergy which in turn maximized our efficiency. Over the course of the semester, we became familiar with each other's schedules, working styles, and skill sets. I, personally, felt most comfortable doing the writing and least comfortable doing the code, so the team adapted to accommodate my preferences. I think that the idea of accommodating for different skill sets will be critical in the workplace; different companies employ a wide range of engineers and non-engineers with vastly different specializations as large-scale projects often require multiple angles and approaches to create effective solutions. Becoming familiar with each other's schedules was also essential as, depending on the week, we knew to let the acting project manager know how busy we were each day for them to get a better idea of how much work to assign everyone.

WORKS CITED

[1] "EDGE Exhibit Designs for Girls' Engagement," 22 August 2016. [Online]. Available: https://www.exploratorium.edu/education/research-evaluation/edge.

[2] Exploratorium, "EDGE- Exhibit Designs for Girls' Engagement | Exploratorium," 16 June 2021. [Online]. Available: https://www.youtube.com/watch?v=Z4_TY4X9XCo.

[3] "Universal Design for Museum Learning Experiences," [Online]. Available: https://www.mos.org/UniversalDesign.

[4] B. D. Jee and F. K. Anggoro, "Designing Exhibits to Support Relational Learning in a Science Museum," 26 March 2021. [Online]. Available: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.636030/full.

[5] E. Schuster, "Exhibit Tips from Around the World," January 2014. [Online]. Available: https://www.astc.org/astc-dimensions/exhibit-tips-from-around-the-world/.

[6] [Online]. Available: https://www.imagineexhibitions.com/exhibitions/top-secret.

[7] R. Shulman, "What is a "good" science demonstration?," 11 January 2016. [Online]. Available: https://museumquestions.com/2016/01/11/what-is-a-good-science-demonstration/.

[8] "The UDL Guidelines," [Online]. Available: https://udlguidelines.cast.org/.

[9] V. Krsmanovic, "Arduino Morse Code Machine," 20 March 2017. [Online]. Available: https://www.hackster.io/vladakrsmanovic/arduino-morse-code-machine-709cc5.

[10] H. Koester, "Morse code for access: what do we know?," 13 August 2019. [Online]. Available: https://kpronline.com/blog/morse-code-for-access-what-do-we-know/#:~:text=Morse%20code%20can%20be%20an.

[11] "New England Habitats," [Online]. Available: https://www.mos.org/exhibits/new-england-habitats.

[12] "Arctic Adventure," [Online]. Available: https://www.mos.org/exhibits/arctic-adventure.

[13] "Exhibits & Experiences," Spy Museum, [Online]. Available: https://www.spymuseum.org/exhibition-experiences/?gclid=CjwKCAiAheacBhB8EiwAItVO237KNwytuMd2Z1N8U7a4E_0aFGPaT52OqeClUWn67DP5D_-hRcKJohoCkw4QAvD_BwE.

[14] "Morse Code & the Telegraph," HIstory.com, 9 November 2009. [Online]. Available: https://www.history.com/topics/inventions/telegraph.

[15] "Morse Code communications," Britannica, 20 August 2022. [Online]. Available: https://www.britannica.com/topic/Morse-Code.

[16] G. Wright, "telegraph," TechTarget Network, Feburary 2022. [Online]. Available: https://www.techtarget.com/searchunifiedcommunications/definition/telegraph.

[17] J. Liu, "MacBook Pro 15” with Retina Display (2019)," 17 August 2020. [Online]. Available: https://grabcad.com/library/macbook-pro-15-with-retina-display-2019-1.

[18] G. Chia, "45mm push button with LED," 4 November 2018. [Online]. Available: https://grabcad.com/library/45mm-push-button-with-led-1.

[19] D. Yang, "minibreadboard," 8 October 2020. [Online]. Available: https://grabcad.com/library/minibreadboard-2.

[20] W. Riyanto, "arduino uno," 14 April 2022. [Online]. Available: https://grabcad.com/library/arduino-uno-56.

[21] G. Baranov, "Piezo Speaker," 31 December 2019. [Online]. Available: https://grabcad.com/library/piezo-speaker-1.

[22] "CYBERSECURITY," Cybersecurity & Infrastructure Security Agency, [Online]. Available: https://www.cisa.gov/cybersecurity.

[23] "Fastest speed for a morse code transmission," Guinness World Records, [Online]. Available: https://www.guinnessworldrecords.com/world-records/fastest-speed-for-a-morse-code-transmission/.

[24] "MORSE CODE HISTORY," Casouls, [Online]. Available: https://www.casouls.com/pages/morse-code-history.

[25] "Fighting talk: First World War telecommunications," National Archives, [Online]. Available: https://www.nationalarchives.gov.uk/first-world-war/telecommunications-in-war/.

AUTHOR BIOGRAPHIES

Danny Liu was born in Lower Manhattan, New York City, in 2004, but raised in Lyndhurst, New Jersey. He is currently majoring in bioengineering at Northeastern University, Boston, MA, and is anticipated to graduate with the class of 2026

From 2016 to 2022, he studied pre-engineering concepts at the Academies at Englewood's Pre-engineering program. During his studies, he worked on a project that enhanced the everyday mask to improve audio recognition. In addition, he worked on an assistive device prototype for those with impaired motor functions.

Mr. Liu believes his faith life is an integral part of his identity and is a member of the Northeastern Soon Movement.

Aryan S. Kalaskar was born in Dharwad, Karnataka, India in 2004. He is currently majoring in computer engineering and computer science at Northeastern University, Boston, MA, and is anticipated to graduate with the class of 2026. Before studying at Northeastern University, he completed his Gujarat Secondary and Higher Secondary Education Board Higher Secondary School Certificate in 2022.

His previous experiences include working on a machine learning project based on Stanford's MURA dataset alongside engineering students in India. Additionally, he has researched the feasibility of using effluent and sewage waste to generate energy at a sewage and effluent water treatment plant (STP and ETP) in India.

Mr. Kalaskar has been associated with Roxbury Robotics and AeroNU clubs at Northeastern University.

Zachary Benjamin Jose Usher is a current first year attending Northeastern University majoring in the Chemical Engineering and Biochemistry combined program with an expected graduation year of 2026. He was originally born in Barnet, United Kingdom but has lived in Massachusetts for over 16 years. He attended Xaverian Brothers High School in Westwood, Massachusetts where he graduated as Salutatorian of the Class of 2022 with high awards in Mathematics, Science, and Social Studies

In high school, he was heavily involved in debate and political clubs including Model UN and the Speech and Debate team as well as in the makerspace. He owes much of his interest in Chemistry to his high school Chemistry teacher, Mr. Howard, who he took both AP Chemistry and Biochemistry classes with. He has a variety of interests including hiking, swimming, cooking, and playing chess. He has also worked several jobs in the childcare field including being a math tutor, a summer camp counselor, and as general daycare staff.

At Northeastern, Mr. Usher is involved in the Biochemistry Club, the American Institution of Chemical Engineers (AICHE) as well as Roxbury Robotics.

APPENDICES

APPENDIX A – TEAM CONTRACT

This is a contract agreed upon between Aryan, Danny, and Zachary on how they will interact throughout the semester. It outlines the expectations put forth by all three of the members and the procedures that will be followed if any expectations are to be violated. This contract also outlines the group roles and goals of each team member and the ways in which they can meet them. This contract will contain the following elements:

- Contact Information
- Team name
- Respect
- Commitment
- Transparency
- Communication
- Justice
- Team goals
- Team roles
- Team Calendar

Contact Information

Name	Email	Phone Number
Danny Liu	liu.dann@northeastern.edu	718-219-3589
Aryan Kalaskar	kalaskar.a@northeastern.edu	857-313-0607
Zachary Usher	usher.z@northeastern.edu	781-535-2762

Team Name

Our primary team name will be the Chimera, the mythical hybrid creature that consists of a lion's head and a goat's head protruding from its back along with a snake's tail. Our second choice will be the mythical phoenix. Our last resort will be the mythical dragon.

Respect

- What is your definition of work lateness and policy for organized submission?

    - An assignment that is considered late will be when it is over 12 hours after a set due date
    - We will be submitting/sharing elements of the project on google drive.
- What is your definition of meeting punctuality and procedure for a successful meeting?
    - Team members are expected to be on time and ready to work. They should not be preoccupied with any other work. At the beginning of the meeting we should jot down our agenda on the whiteboard.
    - We will meet twice a week(more or less, depending on the workload) on Mondays and Wednesdays starting from 6:00 PM and ending no later than 8:00 PM.
- What will be the procedure if someone violates these expectations?
    - They've got to buy the team something worth $5 from Dunkin' Donuts.
    - Each consecutive violation will draw an extra penalty of $5 worth of food from Dunkin' Donuts.

Commitment

- What hours do you expect people to be available to meet? Answer questions?
    - Monday and Wednesday evenings from 6:00 pm to 8:00 pm.
- What will be the procedure if someone violates these expectations?
    - They've got to buy the team something from Dunkin' Donuts.
    - Each consecutive violation will draw an extra penalty of $5 worth of food from Dunkin' Donuts.
- What will your expectations for quality be? / How will you measure this value?
    - Completing the agenda before ending the meeting.
    - Efficiency/Quality can be calculated in the following way:
      Efficiency = Portion of Agenda Points Completed/Total Agenda Points
    - We will maintain a spreadsheet or a gantt chart or both to record our quality.

Transparency

- How will your team make decisions? / What will be the threshold for consensus?
    - As we have 3 team members, if it comes down to it, we could vote between two options.
    - We could do a strength and weakness analysis chart.
- How will you ensure all information is shared and open to all?
    - We will share documents on google drive. We can share any urgent information regarding due dates or incomplete work over a texting group chat.
- What will be the procedure if someone feels excluded?
    - If a team member feels excluded, they are expected to communicate this with the rest of the team. The team will then work to resolve the issue, if

left unresolved, the team member should then speak with the Teaching Assistant(TA) and, if required, with Prof.O'Connel.

Justice

- How will you define equitable contribution?
    - Equitable contribution is defined as using the skills and abilities an individual possesses to work towards the team goal.
- How will your group work to prevent conflict?
    - Be considerate of the skills and abilities of our fellow teammates. Criticize the work and never the person doing it. Remember that we are not competing and we should always offer each other assistance if needed.
- What will be the procedure if someone stops contributing?
    - If someone stops contributing, it will be considered as incompetency and will draw the same penalty as a violation of expectations.

Team Goals

- Make a list of 4 or more goals as a team for improving your team skills
    - Become familiar with teammates' working styles
    - Punctuality
    - Building good team atmosphere
    - Develop efficient problem solving skills/systems
- Make a list of 2 or more goals for each individual
    - Aryan Kalaskar
        - Have good Problem-Solving skills
        - Bond
        - Writing neatly on the whiteboard
    - Danny Liu
        - Leadership skills
        - Experience in coding/autoCAD and circuitry
    - Zachary Usher
        - Improve coding
        - Get hands-on experience

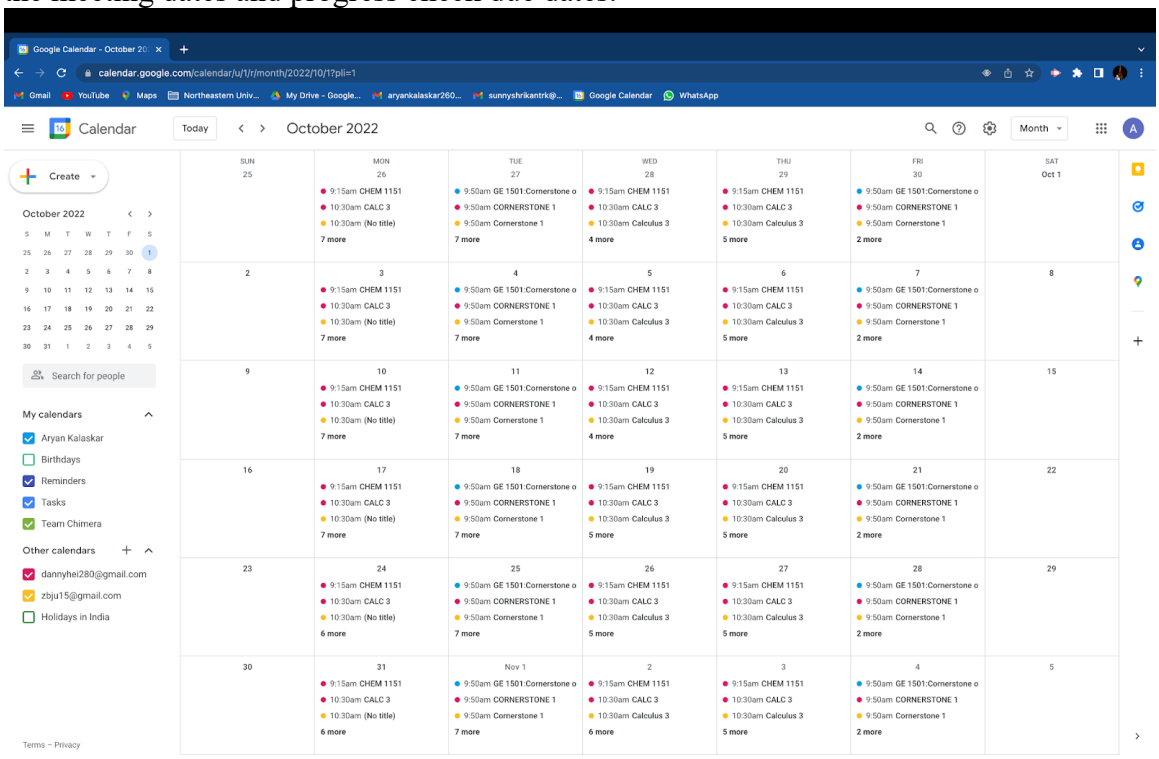
Team Roles

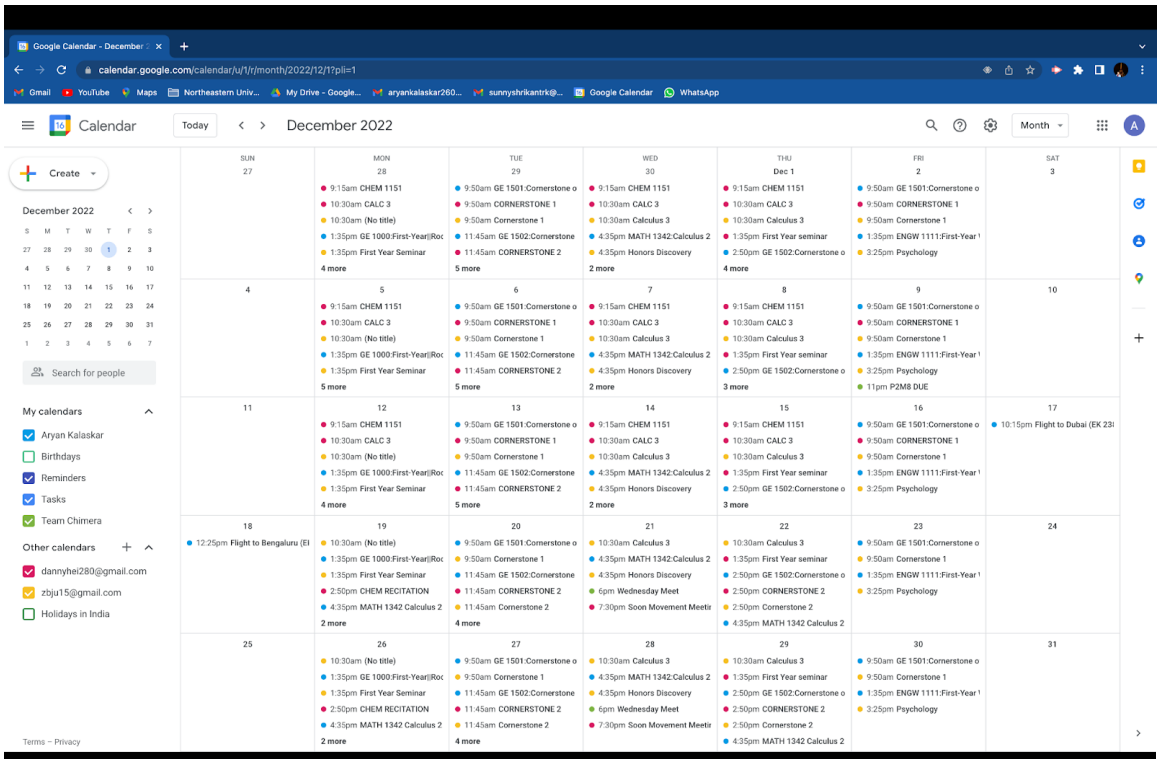
- Project Manager for M1- Zachary
- Project Manager for M2- Danny
- Project Manager for M3- Aryan
- Project Manager for M4- Zachary

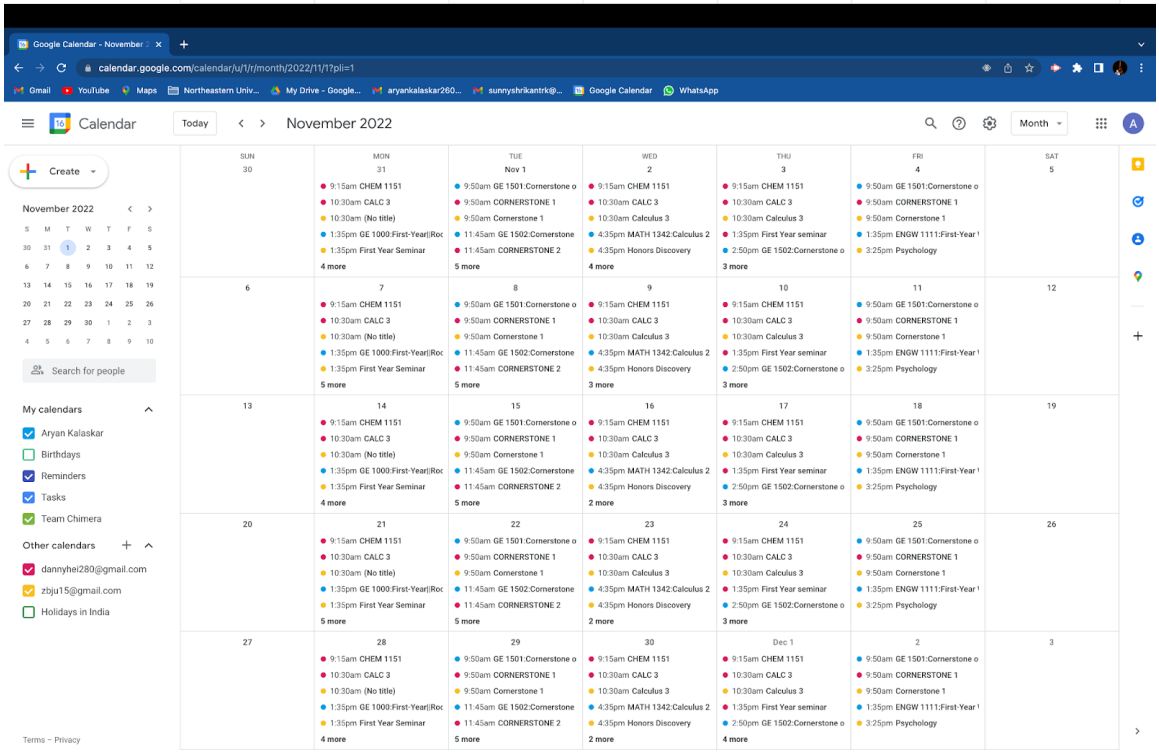
These roles are tentative and subject to change.
This applies to Project 2, not Project 1.

Team Calendar

The group created their own individual Google Calendars. Afterwards, they all shared their individual calendars with another, thus compiling everyone's schedules in one Google Calendar. They then also created a "Team Chimera" calendar that compiles all the meeting dates and progress check due dates.

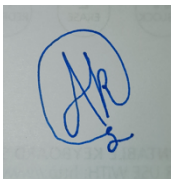



Google Calendar - December
calendar.google.com/calendar/u/1/r/month/2022/12/1?pli=1
Calendar
Today
December 2022
Month
Create
December 2022
Search for people
My calendars
Aryan Kalaskar
Birthdays
Reminders
Tasks
Team Chimera
Other calendars
dannyhei280@gmail.com
zbju15@gmail.com
Holidays in India
Terms – Privacy
SUN 27
MON 28
TUE 29
WED 30
THU Dec 1
FRI 2
SAT 3
9:15am CHEM 1151
10:30am CALC 3
10:30am (No title)
1:35pm GE 1000:First-Year|Roc
1:35pm First Year Seminar
4 more
9:50am GE 1501:Cornerstone o
9:50am CORNERSTONE 1
9:50am Cornerstone 1
11:45am GE 1502:Cornerstone
11:45am CORNERSTONE 2
5 more
10:30am Calculus 3
4:35pm MATH 1342:Calculus 2
4:35pm Honors Discovery
2 more
1:35pm First Year seminar
2:50pm GE 1502:Cornerstone o
3 more
9:50am CORNERSTONE 2
1:35pm ENGW 1111:First-Year
3:25pm Psychology
11pm P2M8 DUE
10:15pm Flight to Dubai (EK 23
12:25pm Flight to Bengaluru (EI
10:30am (No title)
2:50pm CHEM RECITATION
4:35pm MATH 1342 Calculus 2
6pm Wednesday Meet
7:30pm Soon Movement Meetir
2:50pm Cornerstone 2


Google Calendar - November
calendar.google.com/calendar/u/1/r/month/2022/11/1?pli=1
Calendar
Today
November 2022
Month
Create
November 2022
Search for people
My calendars
Aryan Kalaskar
Birthdays
Reminders
Tasks
Team Chimera
Other calendars
dannyhei280@gmail.com
zbju15@gmail.com
Holidays in India
Terms – Privacy
SUN 30
MON 31
TUE Nov 1
WED 2
THU 3
FRI 4
SAT 5
9:15am CHEM 1151
10:30am CALC 3
10:30am (No title)
1:35pm GE 1000:First-Year|Roc
1:35pm First Year Seminar
4 more
9:50am GE 1501:Cornerstone o
9:50am CORNERSTONE 1
9:50am Cornerstone 1
11:45am GE 1502:Cornerstone
11:45am CORNERSTONE 2
5 more
10:30am Calculus 3
4:35pm MATH 1342:Calculus 2
4:35pm Honors Discovery
3 more
1:35pm First Year seminar
2:50pm GE 1502:Cornerstone o
9:50am CORNERSTONE 2
1:35pm ENGW 1111:First-Year
3:25pm Psychology
2 more

Summary

This memo provides details about how Team Chimera is going to function and our expectations each member of the team will put into the project. This serves as a reference point when the team gets lost as they progress through the project or when conflict arises during it.



Aryan Kalaskar

Danny Liu

Zachary Usher

APPENDIX B - DESCISION ANALYSIS

PRIORITIES KTDA

	Ease of Creation	Portability	Interactivity	Durability	Safety	Total
Ease of Creation	-	0	-1	-1	-1	-3
Portability	0	-	-1	-0.5	-1	-2.5
Interactivity	1	1	•	0.5	0	2.5
Durability	1	0.5	-1	•	-1	-0.5
Safety	1	1	0	1	•	3

Through some brainstorming as a Team, these five priorities or design goals that were proposed. From these five, they are compared to one another with scores ranging from -1 to 1. -1 being the column priority is more important and 1 being the row priority being more important. In addition, a 0 means they are equally as important.

TOPIC KTDA

Ayan Kalaskar

Priority Compared To (Assigned Wt.) Topic	Ease of Creation (2)	Portability (3)	Interactivity (9)	Durability (6)	Safety (10)	Total	Total (Weighted)
Radar	4	5	7	4	9	29	200
Enigma Machine	7	8	6	5	10	36	222
Two-Way Mirror	9	4	4	6	5	28	152
Cybersecurity	3	5	7	6	6	27	180
Morse Code Game	8	7	8	8	10	41	257
Listening Machine	4	9	6	8	9	36	227

Through some brainstorming as a Team, 6 different topics were generated. Each topic is ranked from a scale of 1-10 on if the topic would be meet the priority brainstormed before. Each priority has a weight base off its total score from the Priorities KTDA and the scale and weight are multiplied to create the total weighted score of each topic. This is Aryan Kalaskar's individual KTDA chart with the Morse code topic with the highest score of 257.

Danny Liu

Priority Compared To (Assigned Wt.) Topic	Ease of Creation (2)	Portability (3)	Interactivity (9)	Durability (6)	Safety (10)	Total	Total (Weighted)
Radar	4	6	5	7	8	30	193
Enigma Machine	6	6	3	4	7	26	151
Two-Way Mirror	6	4	6	5	6	27	168
Cybersecurity	2	6	7	5	6	26	175
Morse Code Game	7	7	8	8	8	38	235
Listening Machine	7	6	5	4	6	28	161

Through some brainstorming as a Team, 6 different topics were generated. Each topic is ranked from a scale of 1-10 on if the topic would be meet the priority brainstormed before. Each priority has a weight base off its total score from the Priorities KTDA and the scale and weight are multiplied to create the total weighted score of each topic. This is Danny Liu's individual KTDA chart with the Morse code topic with the highest score of 235.

Zachery Usher

Priority Compared To (Assigned Wt.) Topic	Ease of Creation (2)	Portability (3)	Interactivity (9)	Durability (6)	Safety (10)	Total	Total (Weighted)
Radar	3	7	8	7	9	34	231
Enigma Machine	6	8	6	5	8	33	200

Two-Way Mirror	8	6	8	6	7	35	212
Cybersecurity	8	7	5	9	8	37	216
Morse Code Game	5	6	9	8	7	35	227
Listening Machine	6	8	7	8	8	37	227

Through some brainstorming as a Team, 6 different topics were generated. Each topic is ranked from a scale of 1-10 on if the topic would be meet the priority brainstormed before. Each priority has a weight base off its total score from the Priorities KTDA and the scale and weight are multiplied to create the total weighted score of each topic. This Zachary Usher's individual KTDA chart with the radar topic with the highest score of 231.

Overall

Priority Compared To (Assigned Wt.) Topic	Ease of Creation (2)	Portability (3)	Interactivity (9)	Durability (6)	Safety (10)	Total	Total (Weighted)
Radar	3.6666666	6	6.66666667	6	8.66666667	31	208
Enigma Machine	6.3333333	7.3333333	5	4.666667	8.33333333	31.6667	191
Two-Way Mirror	7.6666667	4.6666667	6	5.666667	6	30	177.33333
Cybersecurity	4.3333333	6	6.33333333	6.666667	6.66666667	30	190.33333
Morse Code Game	6.6666667	6.6666667	8.33333333	8	8.33333333	38	239.66667
Listening Machine	5.6666667	7.6666667	6	6.666667	7.66666667	33.6667	205

From the individual KTDA charts, an overall KTDA chart is created by averaging all the numbers in the table. The highest overall total weighted score is the Morse code topic with a score of around 240.

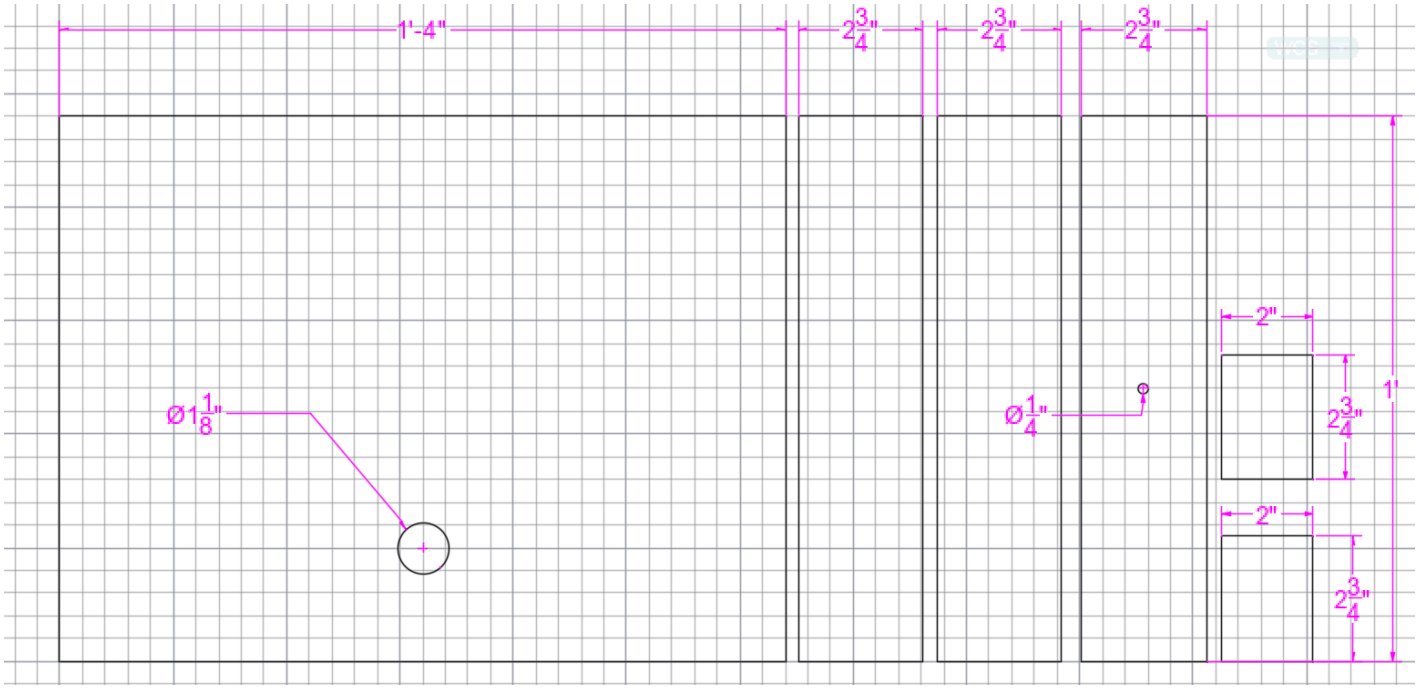
FINAL SOLUTION KTDA

	Ease of Creation	Portability	Interactivity	Durability	Safety	Total:	Weighted Total
Weight	2	3	9	6	10	•	•
Monkey Type	8	9	8	8	10	40	263
Number Memory	6	9	8	7	10	40	253
Type-racer	5	8	10	6	10	39	260
Piano tiles	4	9	10	5	10	40	255
Sequence Memory	7	8	7	6	10	38	237

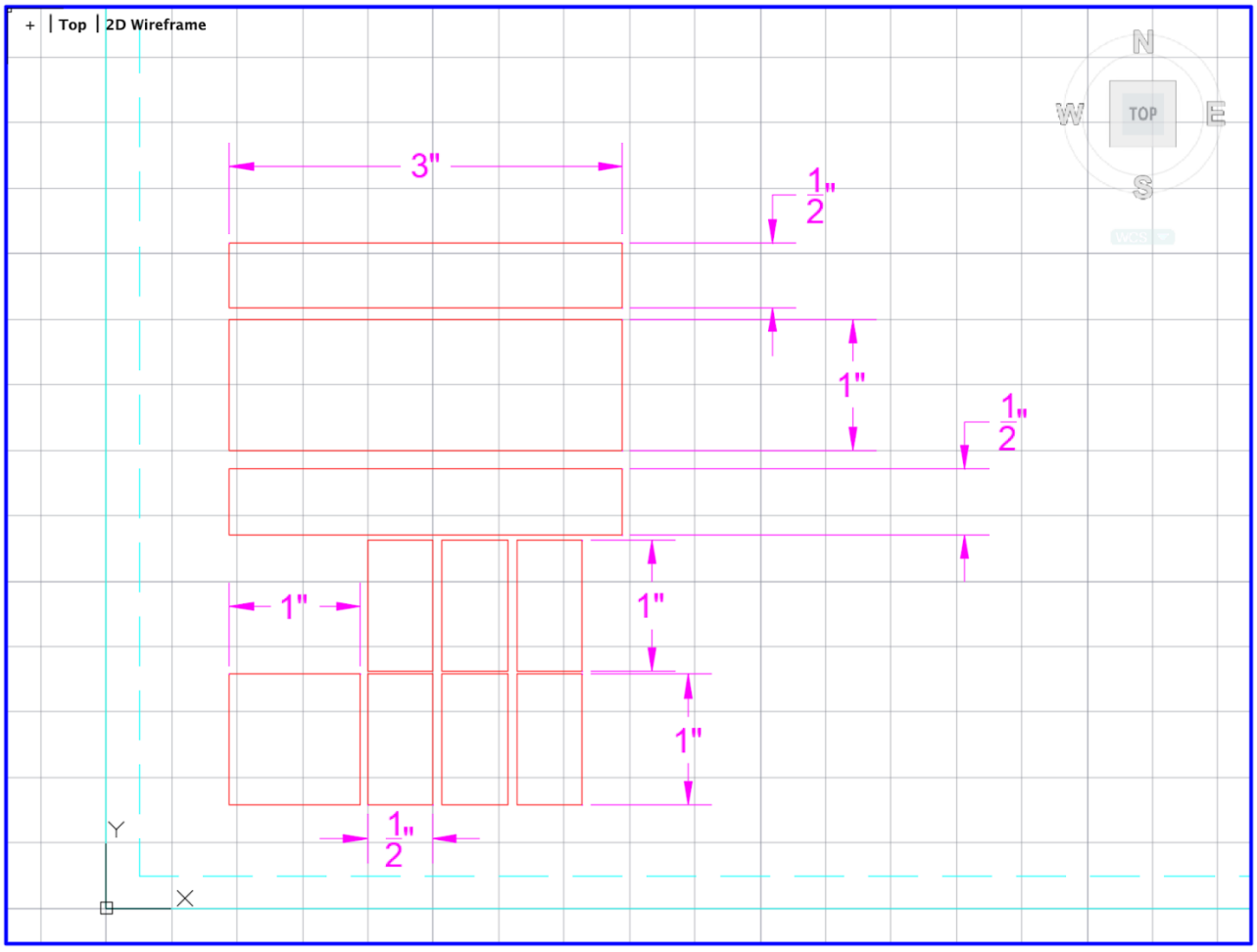
Over brainstorming and using SCAMPER to come up with different solutions. The 6 different ideas are ranked from a scale of 1-10 on if the idea would be meet the priorities of the same rank similarly to the Topic KTDA charts. The highest weighted total was Monkey Type idea with a score of 263.

APPENDIX C - AUTOCAD/SOLIDWORKS DRAWINGS

AUTOCAD OF WOOD TO BE LASER CUT

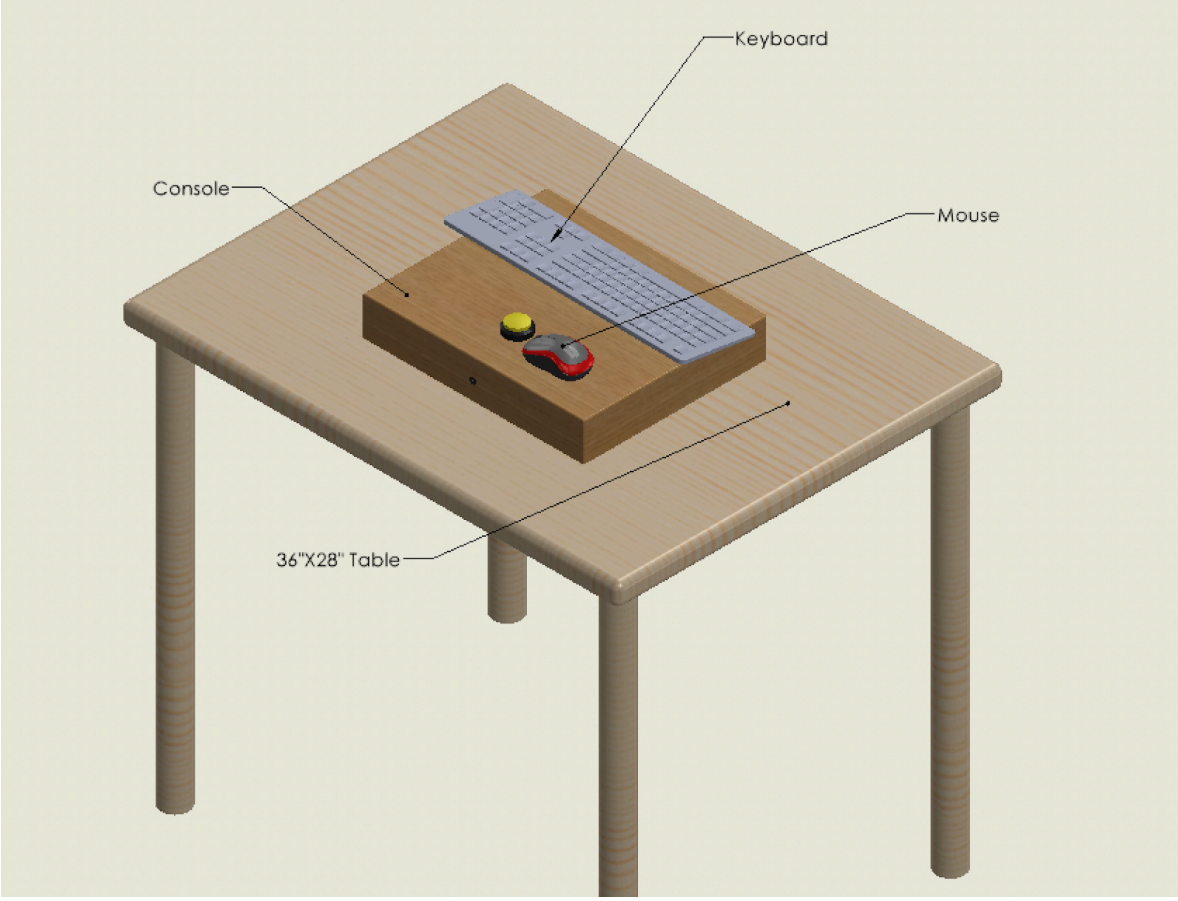


AUTOCAD OF ACRYLIC TO BE LASER CUT

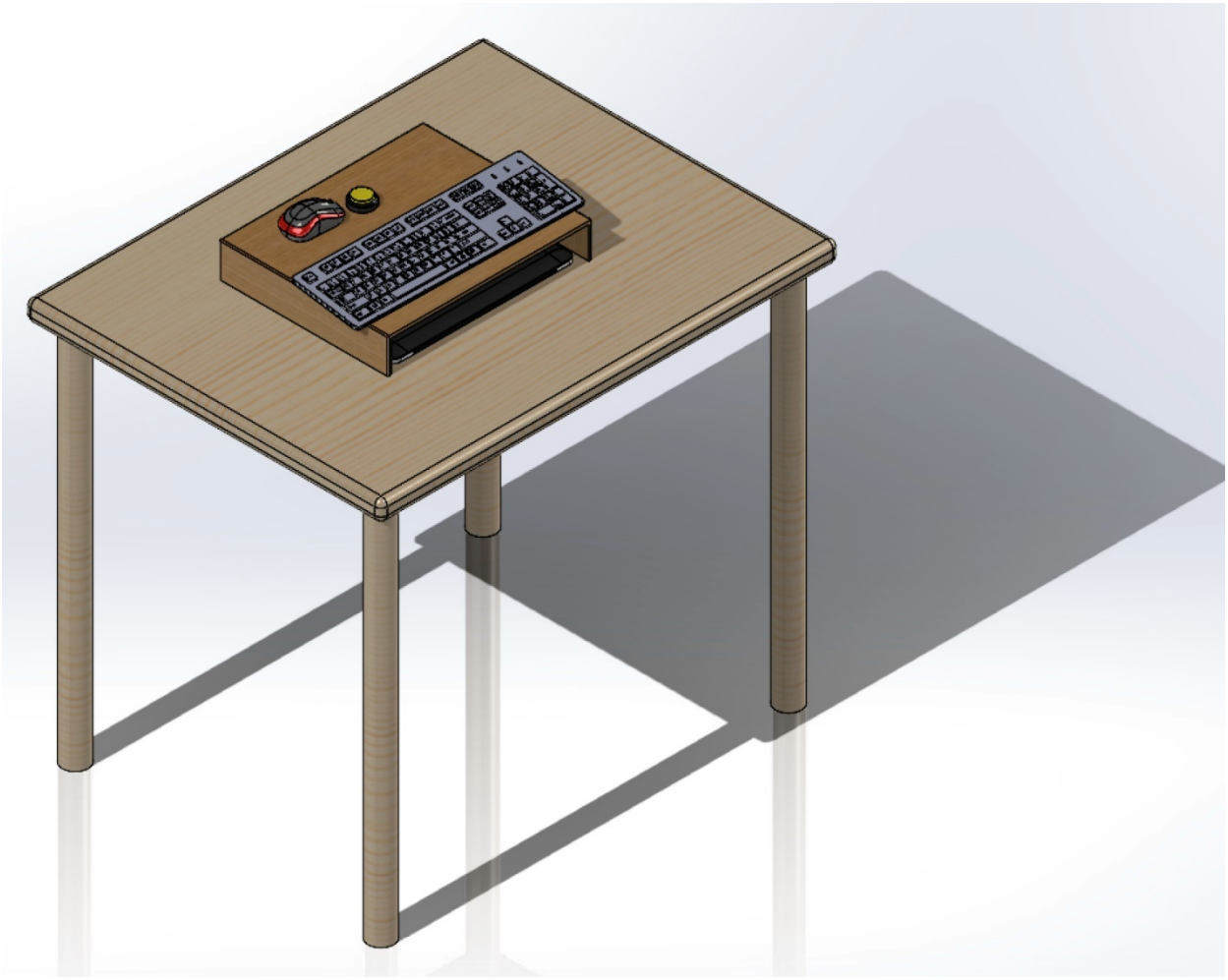


SOLIDWORKS REPRESENTATION OF TRANSPORT CONFIGURATION

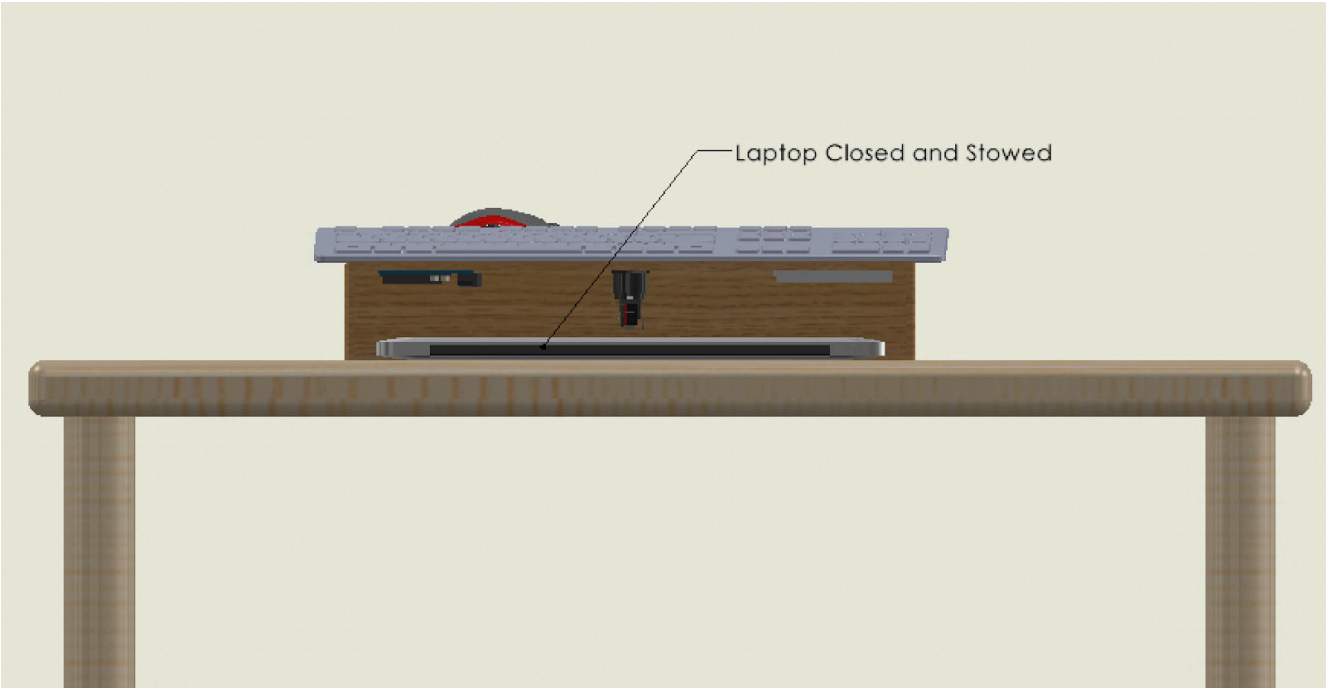
A-1



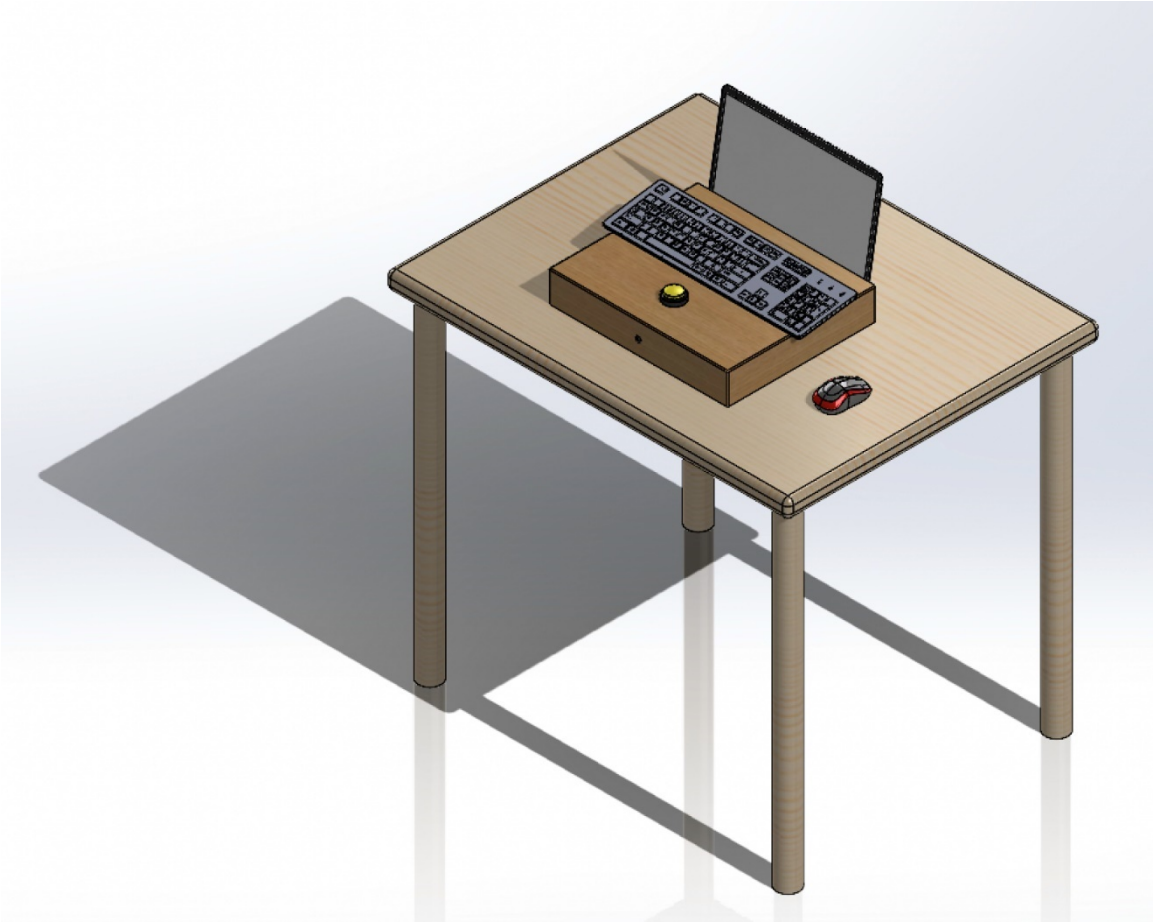
A-2



A-3

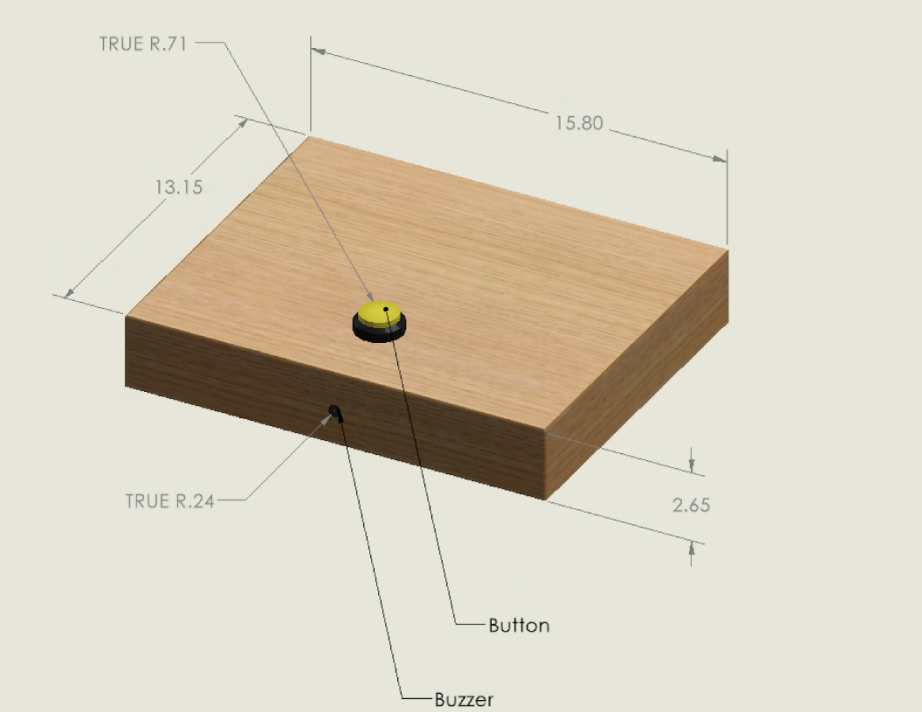


SOLIDWORKS REPRESENTATION OF FULL SET UP CONFIGURATION

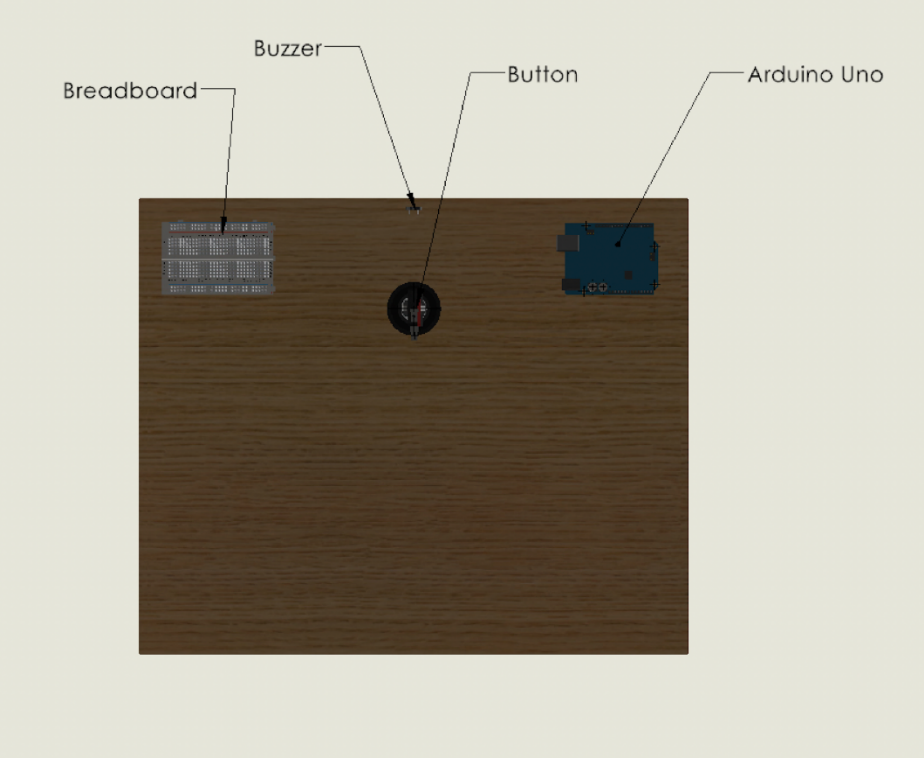


SOLIDWORKS REPRESENTATION OF THE CONSOLE

B-1



B-2



APPENDIX D – PRODUCT TESTING RESULTS

EVALUATION PLANNING TABLE

Requirements	Data to Collect	Reasoning	Method	Analysis
Ease of Creation	• Time spent on project (hours) • Stress among team members	"Difficulty" can be measured in both time spent on a task as well as how much mental space the task takes up.	• Hours log • Self Report Methodology	Compare hours log to project 1 milestone hours logs. Low levels of stress reported in stress surveys corresponds with easier creation
Portability	• Physical measurements (in, lbs)	The project already outlines a size requirement, so the portability should match up with that. The project should also be light enough such that a single person should be able to lift without difficulty.	• Tape measurer • Weight testing • Box testing	The measurements recorded by the tape measurer should be compared to the constraints. Positive results in the box test and the weight test would also indicate adequate portability
Interactivity	• Time spend engaging with exhibit (minutes) • Entertainment value	Interactivity is an abstract concept, so the best way to measure it is to measure the amount of time people are engaged with the exhibit. Self-report methodology	• Timed tests with subjects • Self-report methodology	The more time a user is engaged, the more interactive the exhibit is. Prompting the users with "I thought that this exhibit was interactive" coupled with a strongly disagree to agree will also gauge interactivity.

		would also be useful to gain the user's perspective.		
Durability	• # of sustained uses before 'damage'	Durability corresponds with the amount of uses the exhibit can sustain without any damage to the equipment including the hardware and software	• Controlled testing with subjects	The more uses without sustaining damage, the more durable the experiment is.
Safety	• # of injuries / total uses	An easy way to gauge safety is to see whether or not the device causes injuries. Since the exhibit is mostly software based, the only possible expected injury are splinters but even those are unlikely.	• Controlled testing with subjects • Self-report methodology	A lower ratio of uses with injuries to total uses means that the device is safer. The self-report surveys could also gauge whether the users felt safe at the exhibit from the user's perspective.

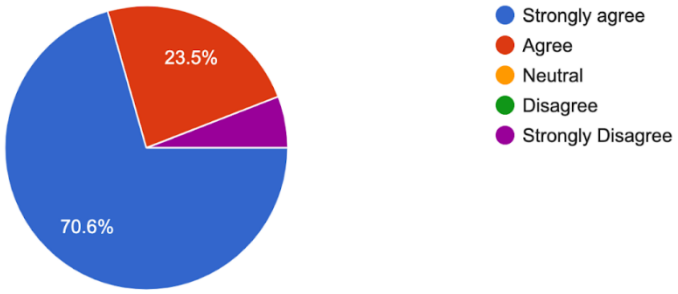
GOOGLE FORM RESULTS

Timestamp	What is your major?	What is your age?	I felt like the exhibit was s	I felt that the exhibit engag
11/22/2022 10:26:23	Computer engineering	18	Strongly agree	Agree
11/22/2022 10:30:14	Civil engineering	18	Strongly agree	Strongly agree
11/22/2022 10:50:29	engineering	17	Strongly agree	Strongly agree
11/22/2022 10:52:11	Civil engineering	18	Strongly agree	Strongly agree
11/22/2022 10:58:45	cheme	18	Strongly agree	Strongly agree
11/22/2022 14:41:41	BioE	17	Strongly agree	Strongly agree
12/2/2022 10:09:07	N/A	17	Strongly agree	Agree
12/2/2022 10:09:19	N/A	17	Strongly agree	Strongly agree
12/2/2022 10:12:33	Still in highschool	17	Strongly agree	Strongly agree
12/2/2022 10:20:24	Computer Science and Bu	18	Strongly agree	Strongly agree
12/2/2022 10:37:04	Don't have one	15	Strongly agree	Strongly Disagree
12/2/2022 10:43:28	Undecided	17	Strongly agree	Agree
12/2/2022 10:45:01	Computer engineering	18	Strongly agree	Agree
12/2/2022 10:46:14	Chemical Engineering	22	Strongly agree	Strongly agree
12/2/2022 10:51:10	Civil	18	Strongly agree	Strongly agree
12/2/2022 10:56:54	Bioengineering	21	Strongly agree	Strongly agree
12/2/2022 11:22:26	Biochemistry	18	Strongly agree	Strongly agree

Do you have any recommendations for us to improve our exhibit?
Maybe make a more challenging mode? It might be really easy for older kids
not break!
perhaps use a touch screen computer to make user interface easier
Faster reaction speed from when i press the button to what the output is
The time between the tests made it so id accidently click and the next one would start and in an attempt to get one done I'd accidently skip between some tests and get them wrong
I suppose start with a tutorial with letters to get someone started but other than that good job.
Maybe another level where you had to use the letters you learned to write words, then phrases, with new letters mixed in. It would make for increased retention and a greater sense of accomplishment, which in turn would increase engagement, which would increase the first two in a positive feedback loop.
Maybe if you are trying to teach younger kids, maybe making a game out of it. Other than that I thought it worked really well.
You did great

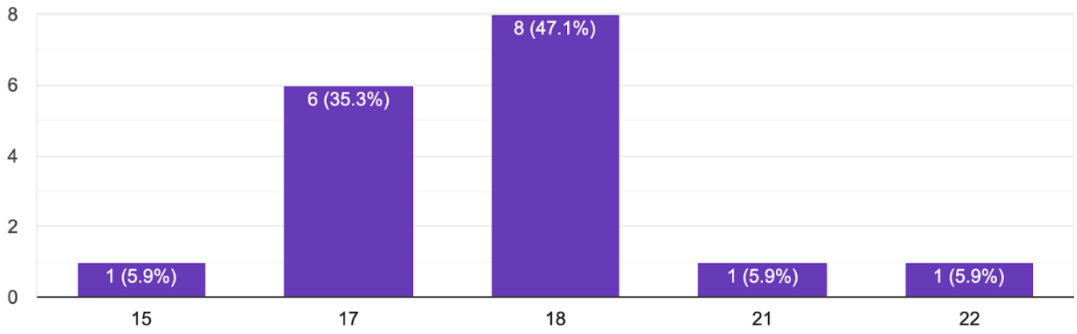
I felt that the exhibit engaged me and kept my attention

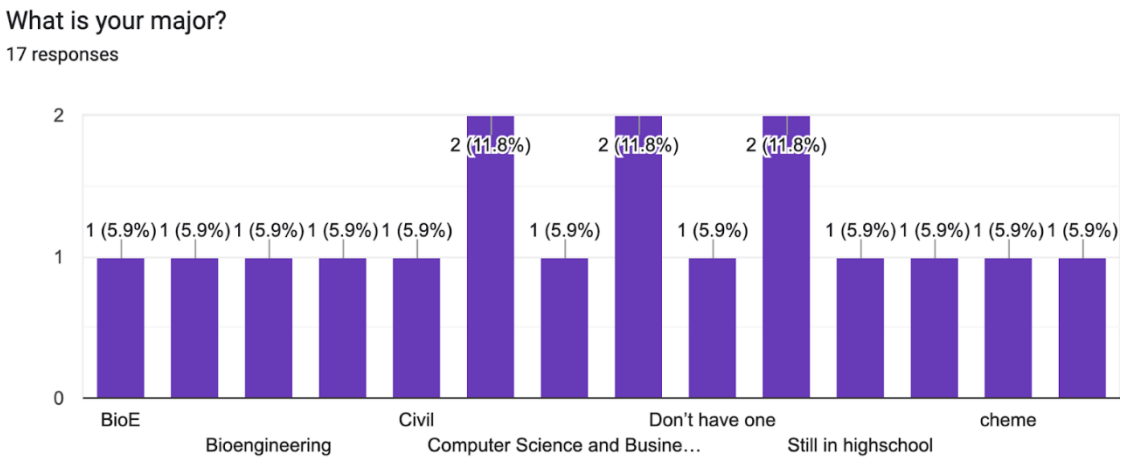
17 responses

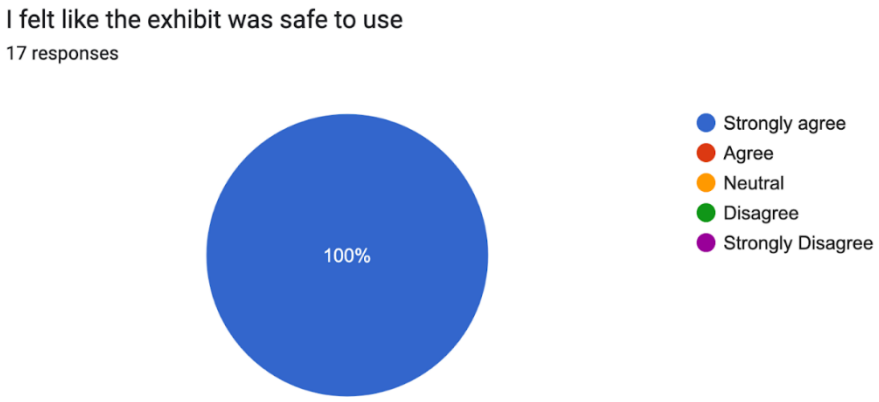


What is your age?

17 responses



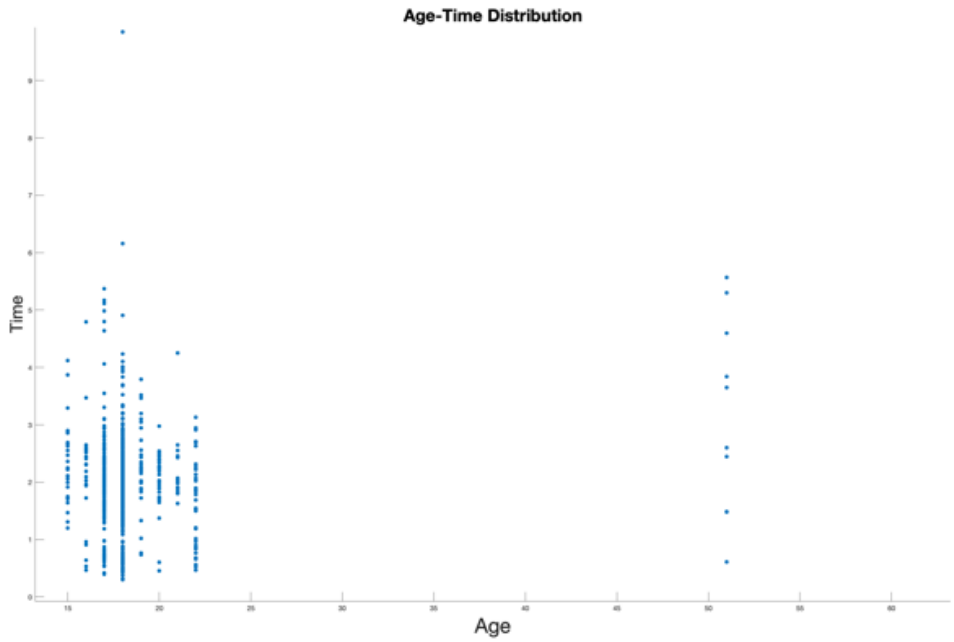




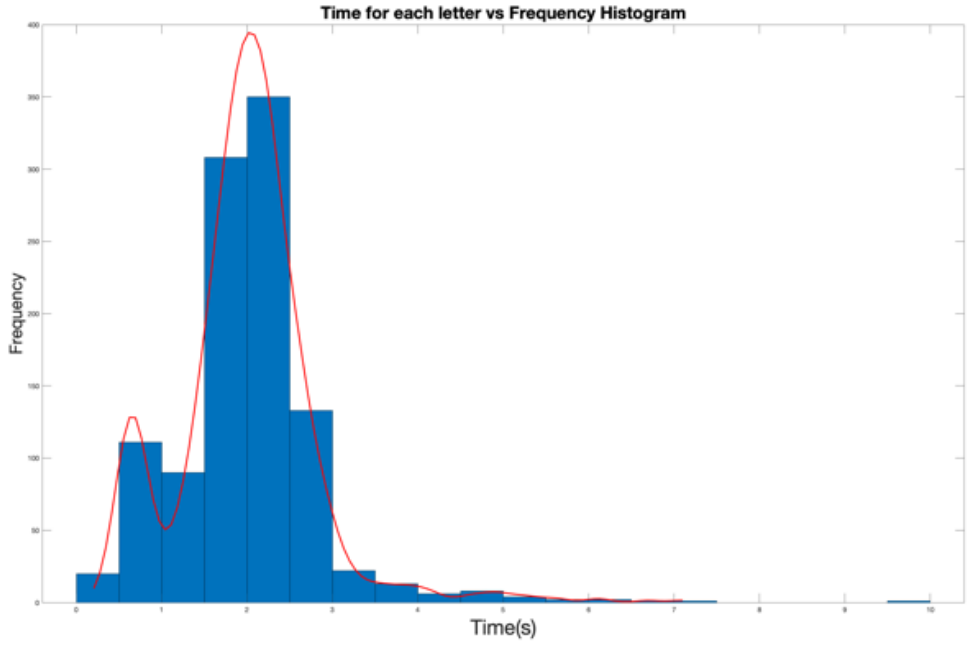
OBSERVATIONAL DATA NOTES

- Two people are trying to compete with their scores
- Decent amount of people in the beginning
- A student commented to me that it was really cool
- People are a little confuse with the dashes (not holding long enough)
- A staff member thought it was cool that it gets harder as you go and commented that it's like a trainer to remember Morse code
- People lie about their age (because they are too lazy to put it)

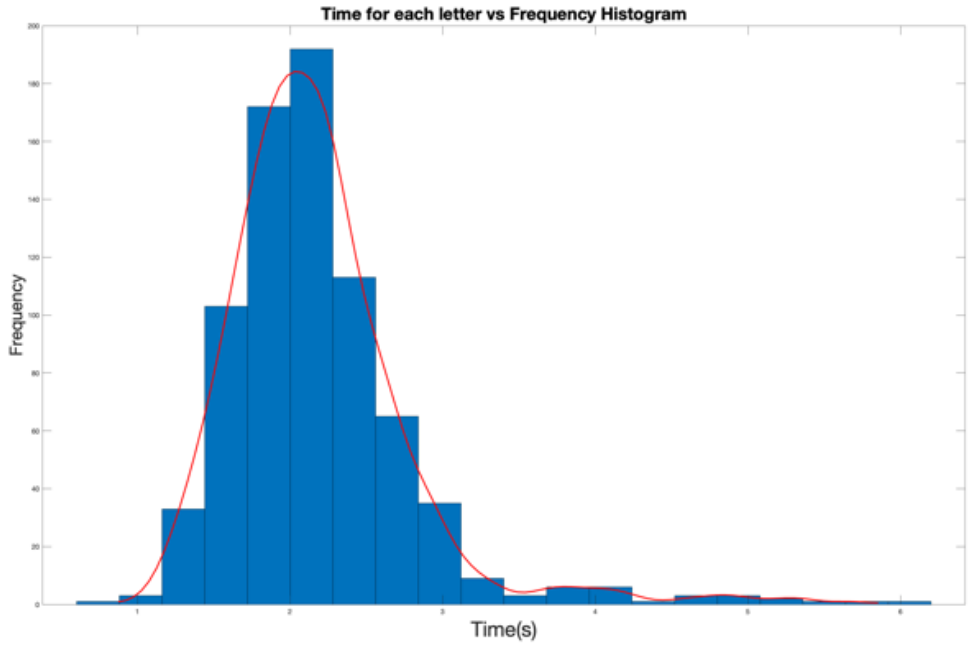
- The data points collected by the autonomous system



Age-Time Distribution scatterplot that plots all the ages and their respective time to type on character of Morse code.



Unfiltered histogram of the amount of time each character took to input vs frequency.



Filtered histogram of the amount of time each character took to input vs frequency

Var1	Var2	Var3	Var4	Var5	Var6
0	18	E	E	1	2.2796
0	18	T	T	1	1.4884
0	18	I	I	1	1.4712
0	18	M	M	1	2.1741
0	18	A	A	1	1.7752
0	18	N	N	1	2.0106
0	18	S	S	1	1.8791
0	18	R	N	0	1.7849
0	18	O	O	1	3.2118
0	18	U	I	0	1.5426
0	18	F	F	1	2.6756
0	18	D	D	1	1.9118
0	18	W	T	0	3.9251
0	18	G	G	1	2.8973
10	18	E	E	1	1.7216
10	18	T	T	1	1.8503
10	18	I	I	1	1.7704
10	18	M	M	1	2.3248
10	18	A	A	1	2.0228
10	18	N	N	1	1.9991
10	18	S	S	1	1.8238
10	18	R	W	0	2.2876
10	18	O	O	1	2.7126
10	18	U	U	1	2.3085
10	18	F	F	1	2.539
10	18	D	D	1	2.2591
10	18	W	W	1	2.9005
0	18	E	T	0	1.8943
0	18	T	T	1	1.6988
0	18	I	I	1	1.6076
0	18	M	M	1	2.2212
0	18	A	A	1	1.9842
0	18	N	N	1	1.8944
0	18	S	S	1	1.8075
0	18	R	R	1	2.2103
0	18	O	O	1	2.6359

0	18	U	U	1	2.0842
0	18	F	F	1	2.3486
0	18	D	D	1	2.1302
0	18	W	W	1	2.2872
0	18	G	G	1	2.3032
0	18	E	T	0	2.8655
0	18	T	T	1	1.9792
0	18	I	I	1	1.6429
0	18	M	M	1	2.1349
0	18	A	A	1	1.8254
0	18	N	N	1	1.8527
0	18	S	S	1	1.7141
0	18	R	R	1	2.2218
0	18	O	W	0	2.2784
0	18	U	U	1	2.9142
0	18	F	F	1	2.427
0	18	D	D	1	2.1878
0	18	W	W	1	2.2782
0	18	G	G	1	2.2642
0	18	E	E	1	2.1873
0	18	T	T	1	2.1063
0	18	I	I	1	1.9274
0	18	M	M	1	2.4205
0	18	A	A	1	2.3629
0	18	N	M	0	2.3221
0	18	S	S	1	2.1686
0	18	R	R	1	2.4001
0	18	O	O	1	3.0249
0	18	U	U	1	2.6937
0	18	F	I	0	1.6059
0	18	D	T	0	0.83444
0	18	W	W	1	3.3476
4	17	E	E	1	1.8675
4	17	T	T	1	1.4953
4	17	I	I	1	1.3223
4	17	M	T	0	1.5468
4	17	A	A	1	2.0513

4	17	N	M	0	1.9463
4	17	S	S	1	1.8208
4	17	R	R	1	1.828
4	17	O	O	1	2.1199
4	17	U	U	1	1.9441
4	17	F	F	1	1.9713
4	17	D	D	1	1.6922
4	17	W	W	1	2.2407
4	17	G	G	1	1.9602
4	17	K	K	1	2.08
4	17	H	H	1	1.5609
0	17	E	Not A Valid Character	0	1.6658
0	17	T	T	1	1.7529
0	17	I	I	1	1.602
0	17	M	M	1	2.0847
0	17	A	A	1	1.8049
0	17	N	N	1	1.9119
0	17	S	S	1	1.7311
0	17	R	R	1	2.1871
0	17	O	O	1	2.6823
0	17	U	U	1	2.0309
0	17	F	F	1	2.3323
0	17	D	D	1	2.0309
0	17	W	W	1	2.216
0	17	G	G	1	2.1947
0	17	K	K	1	2.5707
0	17	E	E	1	2.0663
0	17	T	T	1	1.3803
0	17	I	I	1	1.4529
0	17	M	M	1	1.7802
0	17	A	A	1	1.5033
0	17	N	N	1	1.652
0	17	S	S	1	1.6454
0	17	R	R	1	1.8506
0	17	O	O	1	2.3034
0	17	U	U	1	1.9172

0	17	F	F	1	2.0785
0	17	D	D	1	1.9907
0	17	W	W	1	2.1035
0	17	G	G	1	2.133
0	17	K	K	1	2.1788
0	17	H	H	1	1.6549
0	17	E	E	1	5.1718
0	17	T	T	1	1.9033
0	17	I	I	1	1.7294
0	17	M	M	1	2.1002
0	17	A	E	0	1.6583
0	17	N	T	0	0.61155
0	17	S	B	0	2.0237
0	17	R	R	1	2.4352
0	17	O	W	0	2.4641
0	17	U	U	1	2.3185
0	17	F	F	1	2.5786
0	17	D	T	0	1.5942
0	17	W	E	0	0.55311
0	17	G	E	0	0.42273
0	17	K	E	0	5.1166
0	17	E	T	0	1.8299
0	17	T	T	1	0.70229
0	17	I	E	0	0.80501
0	17	M	E	0	0.76328
0	17	A	E	0	0.73479
0	17	N	E	0	0.8321
0	17	S	E	0	0.69854
0	17	R	E	0	0.70535
0	17	O	E	0	0.69472
0	17	U	E	0	0.766
0	17	F	E	0	0.69053
0	17	D	E	0	0.6727
0	17	W	E	0	0.76059
0	17	G	E	0	0.70614
0	17	K	E	0	0.72909
0	17	H	E	0	0.70696

0	17	B	E	0	0.73345
0	17	J	T	0	0.7949
0	17	Q	E	0	0.69399
0	17	V	E	0	0.7148
0	17	X	E	0	0.70951
0	17	Y	E	0	0.72617
0	17	Z	E	0	0.66751
0	17	C	E	0	0.66393
0	17	P	E	0	0.68676
0	17	L	T	0	0.53193
0	17	E	T	0	1.8827
0	17	T	T	1	1.6847
0	17	I	I	1	1.4224
0	17	M	M	1	2.1416
0	17	A	A	1	1.6866
0	17	N	N	1	1.6277
0	17	S	S	1	1.5091
0	17	R	R	1	1.9357
0	17	O	O	1	2.4168
0	17	U	U	1	1.9199
0	17	F	F	1	2.0593
0	17	D	D	1	1.8352
0	17	W	W	1	2.2746
0	17	G	G	1	2.1086
0	17	K	K	1	2.318
0	18	E	E	1	2.607
0	18	T	T	1	1.6
0	18	I	I	1	1.7347
0	18	M	M	1	2.0026
0	18	A	A	1	1.9725
0	18	N	T	0	1.4968
0	18	S	E	0	0.57158
0	18	R	E	0	0.87086
0	18	O	O	1	2.2969
0	18	U	U	1	2.3396
0	18	F	F	1	2.6708
0	18	D	D	1	2.3448

0	18	W	W	1	2.5428
0	18	G	G	1	2.6175
0	18	K	K	1	2.5235
0	18	E	E	1	2.7266
0	18	T	T	1	1.7314
0	18	I	I	1	1.763
0	18	M	E	0	1.4303
0	18	A	T	0	0.61085
0	18	N	N	1	2.2978
0	18	S	S	1	2.048
0	18	R	R	1	2.1653
0	18	O	O	1	2.4183
0	18	U	U	1	2.2906
0	18	F	F	1	2.4779
0	18	D	D	1	2.1192
0	18	W	W	1	2.3919
0	18	G	R	0	2.2764
0	18	E	E	1	2.4213
0	18	T	T	1	1.6165
0	18	I	I	1	1.456
0	18	M	M	1	2.0002
0	18	A	A	1	1.89
0	18	N	N	1	1.8762
0	18	S	S	1	1.8218
0	18	R	R	1	2.1457
0	18	O	O	1	2.5749
0	18	U	U	1	2.2769
0	18	F	F	1	2.324
0	18	D	D	1	1.8955
0	18	W	W	1	2.1773
0	18	G	G	1	2.1539
0	18	E	E	1	2.0503
0	18	T	T	1	1.2971
0	18	I	I	1	1.3124
0	18	M	M	1	1.7288
0	18	A	A	1	1.4093
0	18	N	N	1	1.721

0	18	S	S	1	1.4865
0	18	R	R	1	1.8477
0	18	O	O	1	2.4025
0	18	U	U	1	1.7627
0	18	F	F	1	2.1938
0	18	D	D	1	1.9444
0	18	W	W	1	2.2074
0	18	G	G	1	2.1875
0	18	K	K	1	2.2432
0	18	H	H	1	1.9971
2	7	E	E	1	2.4169
2	7	T	T	1	1.0791
2	7	I	I	1	1.1271
2	7	M	M	1	1.6693
2	7	A	A	1	2.0388
2	7	N	N	1	1.4687
2	7	S	S	1	1.3759
2	7	R	R	1	1.9214
2	7	O	O	1	2.8516
2	7	U	U	1	2.0017
2	7	F	F	1	2.2259
2	7	D	W	0	2.339
2	7	W	W	1	3.0564
2	7	G	E	0	1.4942
2	7	K	A	0	1.2695
2	7	H	H	1	1.8004
2	7	E	E	1	2.5327
2	7	T	T	1	1.7455
2	7	I	I	1	1.1995
2	7	M	M	1	2.1674
2	7	A	A	1	1.8084
2	7	N	N	1	1.6187
2	7	S	S	1	1.4996
2	7	R	R	1	1.9524
2	7	O	O	1	2.8525
2	7	U	U	1	2.2014
2	7	F	F	1	2.2735

2	7	D	D	1	1.975
2	7	W	W	1	2.5391
2	7	G	G	1	2.556
2	7	E	E	1	2.3208
2	7	T	T	1	1.6379
2	7	I	I	1	1.4233
2	7	M	M	1	1.8751
2	7	A	A	1	1.7379
2	7	N	N	1	1.4686
2	7	S	S	1	1.339
2	7	R	R	1	1.7414
2	7	O	O	1	2.5696
2	7	U	A	0	1.8946
2	7	F	F	1	2.26
2	7	D	D	1	2.3408
2	7	W	W	1	2.6121
2	7	G	G	1	2.4049
2	7	K	K	1	2.818
2	7	E	E	1	2.6604
2	7	T	T	1	1.2813
2	7	I	I	1	1.237
2	7	M	M	1	1.7807
2	7	A	A	1	1.5934
2	7	N	N	1	1.4316
2	7	S	S	1	1.248
2	7	R	R	1	1.8736
2	7	O	O	1	2.5854
2	7	U	U	1	2.1892
2	7	F	F	1	2.1944
2	7	D	D	1	2.0135
2	7	W	W	1	2.4177
2	7	G	M	0	2.5574
2	7	K	E	0	0.47819
2	7	H	H	1	1.8484
2	7	B	B	1	2.2317
0	18	E	E	1	2.6836
0	18	T	T	1	1.5496

0	18	I	I	1	1.4718
0	18	M	M	1	2.03
0	18	A	A	1	1.8442
0	18	N	N	1	1.5344
0	18	S	S	1	1.2775
0	18	R	R	1	1.9545
0	18	O	O	1	2.4863
0	18	U	U	1	1.9437
0	18	F	F	1	2.2867
0	18	D	D	1	2.4823
0	18	W	W	1	2.7795
0	18	G	G	1	2.4853
0	18	K	R	0	2.075
0	18	H	H	1	1.8866
2	7	E	T	0	2.384
2	7	T	T	1	2.0071
2	7	I	I	1	2.0487
2	7	M	M	1	2.2828
2	7	A	A	1	2.0558
2	7	N	N	1	2.1468
2	7	S	S	1	2.0622
2	7	R	R	1	2.4064
2	7	O	O	1	2.9106
2	7	U	U	1	2.3636
2	7	F	F	1	2.7219
2	7	D	D	1	2.438
2	7	W	T	0	1.9403
2	7	G	R	0	3.1733
2	7	E	E	1	2.6564
2	7	T	T	1	1.6047
2	7	I	I	1	6.0551
2	7	M	Not A Valid Character	0	2.1786
2	7	A	Not A Valid Character	0	2.939
2	7	N	Not A Valid Character	0	4.9367

2	7	S	Not A Valid Character	0	6.6898
2	7	R	T	0	1.8671
2	7	O	E	0	1.9302
2	7	U	E	0	2.6499
2	7	E	E	1	2.7839
2	7	T	T	1	1.5672
2	7	I	M	0	2.3137
2	7	M	M	1	4.5413
2	7	A	A	1	2.1944
2	7	N	N	1	1.8517
2	7	S	S	1	1.6735
2	7	R	R	1	2.0335
2	7	O	Not A Valid Character	0	2.8383
2	7	U	Not A Valid Character	0	7.0808
2	7	F	F	1	2.9423
2	7	E	E	1	3.624
2	7	T	E	0	0.53217
2	7	I	I	1	5.6674
2	7	M	M	1	1.8937
2	7	A	A	1	1.7202
2	7	N	N	1	1.6029
2	7	S	S	1	1.4006
2	7	R	R	1	1.7181
2	7	O	O	1	2.243
2	7	U	A	0	1.9292
2	7	F	F	1	1.9443
2	7	D	D	1	1.8072
2	7	W	W	1	2.1258
2	7	G	G	1	1.9653
2	7	K	E	0	1.0902
11	17	E	E	1	2.64
11	17	T	T	1	1.8488
11	17	I	I	1	2.12
11	17	M	M	1	2.2721
11	17	A	A	1	2.0495

11	17	N	N	1	2.0996
11	17	S	S	1	1.7942
11	17	R	E	0	1.4049
11	17	O	N	0	0.97919
11	17	U	I	0	2.0331
11	17	F	T	0	0.61233
11	17	D	E	0	2.5568
11	17	W	I	0	0.87124
11	17	G	U	0	2.0686
11	17	K	K	1	2.3621
11	17	H	H	1	1.9651
11	17	B	D	0	2.1358
11	17	E	E	1	2.2764
11	17	T	T	1	1.6228
11	17	I	I	1	1.5572
11	17	M	M	1	2.3296
11	17	A	A	1	2.3966
11	17	N	A	0	2.0645
11	17	S	S	1	2.224
11	17	R	R	1	2.1959
11	17	O	O	1	4.0606
11	17	U	U	1	2.6795
11	17	F	Not A Valid Character	0	2.7358
11	17	D	D	1	2.5604
11	17	W	W	1	3.3072
11	17	E	E	1	2.577
11	17	T	T	1	1.4137
11	17	I	I	1	1.6126
11	17	M	M	1	2.0329
11	17	A	A	1	1.6192
11	17	N	N	1	1.8011
11	17	S	S	1	1.8753
11	17	R	R	1	1.9603
11	17	O	E	0	1.1877
11	17	U	T	0	0.64137
11	17	F	E	0	0.75383

11	17	D	D	1	2.0966
11	17	W	W	1	2.2579
11	17	G	G	1	2.0961
11	17	K	K	1	2.3805
11	17	H	H	1	1.8411
11	17	B	B	1	2.0109
11	17	J	H	0	2.3366
12	17	E	E	1	2.638
12	17	T	E	0	2.0014
12	17	I	T	0	2.5679
12	17	M	T	0	3.5464
12	17	A	T	0	0.97353
12	17	N	N	1	4.6404
12	17	S	S	1	2.8186
12	17	R	R	1	2.8666
12	17	O	S	0	1.7972
12	17	U	U	1	5.3748
12	17	F	F	1	2.5982
12	17	E	E	1	2.4004
12	17	T	T	1	2.1522
12	17	I	I	1	1.6308
12	17	M	M	1	2.8122
12	17	A	A	1	1.9875
12	17	N	A	0	1.9576
12	17	S	S	1	1.9394
12	17	R	R	1	2.2391
12	17	O	O	1	3.1085
12	17	U	U	1	2.4239
12	17	F	F	1	2.4427
12	17	D	D	1	2.1927
12	17	W	W	1	2.402
12	17	G	G	1	2.6501
0	18	E	E	1	3.3268
0	18	T	T	1	1.2601
0	18	I	I	1	1.2615
0	18	M	M	1	1.6359
0	18	A	U	0	2.1046

0	18	N	N	1	1.8399
0	18	S	S	1	1.4461
0	18	R	N	0	1.9313
0	18	O	O	1	2.1627
0	18	U	U	1	1.6243
0	18	F	F	1	1.9552
0	18	D	E	0	1.1817
0	18	W	T	0	0.77862
0	18	G	A	0	1.7716
0	18	K	E	0	0.78001
0	18	H	H	1	1.8402
0	18	B	D	0	2.8357
0	18	J	D	0	1.8598
0	18	E	E	1	2.1607
0	18	T	T	1	1.677
0	18	I	I	1	1.6618
0	18	M	T	0	1.4244
0	18	A	T	0	0.83337
0	18	N	A	0	1.3672
0	18	S	S	1	2.2863
0	18	R	R	1	2.1836
0	18	O	O	1	2.7131
0	18	U	U	1	2.1745
0	18	F	F	1	2.438
0	18	D	D	1	2.0633
0	18	W	W	1	2.2493
0	18	G	G	1	2.2412
0	18	K	K	1	2.3786
0	18	H	H	1	1.9716
0	18	E	E	1	3.7006
0	18	T	T	1	1.4917
0	18	I	I	1	1.476
0	18	M	A	0	1.7959
0	18	A	A	1	1.5817
0	18	N	N	1	1.7834
0	18	S	S	1	1.8034
0	18	R	R	1	2.2141

0	18	O	O	1	2.2682
0	18	U	U	1	1.8205
0	18	F	F	1	2.1144
0	18	D	E	0	1.1818
0	18	W	I	0	0.88298
0	18	G	S	0	1.9179
0	18	K	U	0	2.1275
0	18	H	S	0	2.0258
0	18	B	B	1	2.5297
0	18	E	E	1	2.8144
0	18	T	T	1	1.8109
0	18	I	I	1	1.6993
0	18	M	M	1	2.2879
0	18	A	A	1	1.988
0	18	N	N	1	2.1769
0	18	S	S	1	2.0872
0	18	R	R	1	2.4535
0	18	O	M	0	2.4453
0	18	U	T	0	0.67236
0	18	F	F	1	4.2363
0	18	D	T	0	1.7863
0	18	W	I	0	0.71156
0	18	G	G	1	3.3136
0	18	K	K	1	2.773
0	18	E	E	1	2.2497
0	18	T	T	1	1.4631
0	18	I	I	1	1.6453
0	18	M	T	0	1.4527
0	18	A	T	0	0.58254
0	18	N	E	0	0.85909
0	18	S	S	1	1.949
0	18	R	S	0	2.2606
0	18	O	E	0	1.2787
0	18	U	E	0	0.50463
0	18	F	T	0	0.65429
0	18	D	T	0	2.4583
0	18	W	I	0	0.88677

0	18	G	M	0	2.0114
0	18	K	E	0	0.42593
0	18	H	I	0	1.7314
0	18	B	I	0	0.71266
0	18	J	E	0	1.8277
0	18	Q	T	0	0.58553
0	18	V	E	0	1.3971
0	18	X	I	0	0.81707
0	18	Y	T	0	1.7106
0	18	Z	T	0	2.076
0	18	E	E	1	2.2368
0	18	T	T	1	1.4441
0	18	I	N	0	1.536
0	18	M	M	1	1.8633
0	18	A	A	1	1.7403
0	18	N	N	1	1.623
0	18	S	S	1	1.8193
0	18	R	R	1	1.9203
0	18	O	O	1	2.2879
0	18	U	U	1	2.0877
0	18	F	F	1	2.1483
0	18	D	D	1	1.9557
0	18	W	W	1	2.2242
0	18	G	G	1	2.0161
0	18	K	K	1	2.2601
0	18	H	H	1	1.8665
0	18	E	E	1	2.8882
0	18	T	T	1	1.4649
0	18	I	I	1	1.3597
0	18	M	M	1	1.8793
0	18	A	A	1	1.7364
0	18	N	N	1	1.5623
0	18	S	S	1	1.5664
0	18	R	R	1	1.9122
0	18	O	O	1	2.1372
0	18	U	U	1	1.847
0	18	F	F	1	1.9397

0	18	D	D	1	1.7604
0	18	W	W	1	2.0114
0	18	G	G	1	2.0557
0	18	K	K	1	2.1164
0	18	H	H	1	1.6542
0	18	B	B	1	1.8913
0	18	E	E	1	2.4817
0	18	T	T	1	1.3321
0	18	I	I	1	1.2521
0	18	M	M	1	1.6601
0	18	A	A	1	1.4822
0	18	N	N	1	1.6484
0	18	S	S	1	1.4478
0	18	R	R	1	1.821
0	18	O	O	1	2.2704
0	18	U	U	1	1.7973
0	18	F	F	1	2.1688
0	18	D	D	1	1.9109
0	18	W	D	0	1.9641
0	18	G	G	1	2.2639
0	18	K	K	1	2.0588
0	18	H	H	1	1.7046
0	18	B	B	1	2.3076
0	18	E	E	1	2.3853
0	18	T	T	1	1.2275
0	18	I	I	1	1.2354
0	18	M	M	1	1.6918
0	18	A	A	1	1.5426
0	18	N	N	1	1.5763
0	18	S	S	1	1.5893
0	18	R	R	1	1.9063
0	18	O	O	1	2.3232
0	18	U	U	1	1.7185
0	18	F	F	1	2.1264
0	18	D	D	1	1.8873
0	18	W	W	1	2.4356
0	18	G	G	1	2.119

0	18	K	K	1	2.0821
0	18	H	H	1	1.8821
0	18	B	B	1	2.0009
0	19	E	E	1	3.7935
0	19	T	T	1	2.1545
0	19	I	I	1	1.8754
0	19	M	M	1	2.9447
0	19	A	A	1	2.7352
0	19	N	N	1	2.3494
0	19	S	S	1	2.3014
0	19	R	W	0	3.1946
0	19	O	S	0	2.2046
0	19	U	U	1	3.4659
0	19	F	Not A Valid Character	0	3.5208
0	19	D	D	1	3.1036
0	20	E	E	1	2.1911
0	20	T	T	1	1.6464
0	20	I	I	1	1.3727
0	20	M	M	1	1.9489
0	20	A	A	1	1.8942
0	20	N	N	1	1.7352
0	20	S	S	1	1.6868
0	20	R	R	1	2.4007
0	20	O	W	0	2.3828
0	20	U	U	1	2.2713
0	20	F	F	1	2.4477
0	20	D	D	1	2.0294
0	20	W	U	0	2.2819
0	20	G	E	0	1.7086
0	20	K	T	0	0.60654
0	20	H	E	0	0.4546
0	20	B	T	0	2.1287
0	18	E	E	1	2.6673
0	18	T	T	1	2.2069
0	18	I	I	1	2.6884
0	18	M	M	1	4.1051

0	18	A	A	1	2.7329
0	18	N	N	1	2.0935
0	18	S	S	1	2.0969
0	18	R	R	1	2.4496
0	18	O	O	1	2.8952
0	18	U	T	0	1.7924
0	18	F	F	1	3.6802
0	18	D	D	1	2.3691
0	18	E	E	1	2.9367
0	18	T	T	1	1.8404
0	18	I	I	1	1.4976
0	18	M	M	1	2.03
0	18	A	A	1	1.8198
0	18	N	T	0	1.9236
0	18	S	S	1	1.6614
0	18	R	N	0	2.1883
0	18	O	O	1	2.4987
0	18	U	U	1	2.1831
0	18	F	F	1	2.4433
0	18	D	D	1	1.9482
0	18	W	W	1	2.4911
0	18	G	G	1	2.3745
0	18	K	X	0	2.5369
0	17	E	E	1	2.7937
0	17	T	T	1	1.5225
0	17	I	I	1	1.2895
0	17	M	A	0	1.7253
0	17	A	A	1	1.8615
0	17	N	N	1	1.6686
0	17	S	S	1	1.4687
0	17	R	R	1	1.922
0	17	O	W	0	2.4257
0	17	U	U	1	2.1228
0	17	F	F	1	2.3729
0	17	D	D	1	2.2112
0	17	W	W	1	2.4131
0	17	G	G	1	2.3435

0	17	K	K	1	2.5097
0	17	H	H	1	1.8147
10	15	E	E	1	4.1219
10	15	T	T	1	2.0582
10	15	I	I	1	3.2946
10	15	M	M	1	2.8861
10	15	A	A	1	2.6325
10	15	N	N	1	2.555
10	15	S	S	1	2.2361
10	15	R	E	0	2.109
10	15	O	M	0	1.3087
10	15	U	U	1	3.8735
10	15	F	Not A Valid Character	0	2.692
10	15	D	D	1	2.8605
10	15	E	E	1	2.8969
10	15	T	T	1	1.7516
10	15	I	I	1	1.471
10	15	M	M	1	1.9943
10	15	A	A	1	2.1126
10	15	N	N	1	1.9131
10	15	S	S	1	1.7054
10	15	R	R	1	2.2192
10	15	O	S	0	1.7392
10	15	U	U	1	2.2486
10	15	F	F	1	2.6331
10	15	D	S	0	2.6681
10	15	W	E	0	1.6412
10	15	G	M	0	1.2009
10	15	K	D	0	2.4691
10	15	H	H	1	2.36
11	17	E	E	1	2.6839
11	17	T	T	1	2.58
11	17	I	I	1	4.9858
11	17	M	M	1	4.8026
11	17	A	A	1	2.9528
11	17	N	T	0	2.1539

11	17	S	E	0	0.399
11	17	R	R	1	2.9818
11	17	O	O	1	3.0977
11	17	U	U	1	2.9394
11	17	F	F	1	2.9365
0	18	E	E	1	3.1134
0	18	T	T	1	2.2223
0	18	I	I	1	2.1356
0	18	M	M	1	2.6989
0	18	A	A	1	2.9106
0	18	N	N	1	2.5859
0	18	S	S	1	2.4602
0	18	R	R	1	2.8615
0	18	O	O	1	2.9919
0	18	U	U	1	2.842
0	18	F	F	1	2.6773
0	18	D	T	0	1.693
0	18	E	E	1	4.9086
0	18	T	T	1	3.8346
0	18	I	I	1	4.014
0	18	M	T	0	2.736
0	18	A	T	0	0.6087
0	18	N	T	0	2.7835
0	18	S	E	0	0.49275
0	18	R	E	0	2.501
0	18	O	T	0	0.76358
0	18	U	U	1	3.1889
0	18	F	F	1	2.5524
0	18	D	D	1	2.3774
0	18	W	E	0	2.7767
0	22	E	E	1	3.13
0	22	T	T	1	2.0651
0	22	I	E	0	1.4982
0	22	M	E	0	0.46999
0	22	A	T	0	1.5472
0	22	N	T	0	0.85892
0	22	S	D	0	1.8412

0	22	R	E	0	1.5155
0	22	O	T	0	0.83699
0	22	U	A	0	1.0131
0	22	F	I	0	1.0182
0	22	D	T	0	0.65659
0	22	W	E	0	0.90249
0	22	G	E	0	0.53026
0	22	K	E	0	1.1903
0	22	H	I	0	2.0737
0	22	B	I	0	0.76821
0	22	J	D	0	2.6902
0	22	Q	T	0	0.68286
0	22	V	E	0	1.2063
0	22	X	E	0	0.56195
0	22	Y	E	0	0.96593
0	22	Z	T	0	2.9495
0	22	E	E	1	3.1336
0	22	T	T	1	1.786
0	22	I	I	1	1.688
0	22	M	M	1	2.2266
0	22	A	A	1	2.0249
0	22	N	N	1	1.8667
0	22	S	S	1	1.898
0	22	R	R	1	2.2663
0	22	O	S	0	2.1335
0	22	U	U	1	2.9134
0	22	F	F	1	2.7106
0	22	D	D	1	2.2178
0	22	W	D	0	2.3165
0	22	G	G	1	2.63
0	18	E	E	1	2.5145
0	18	T	T	1	1.3526
0	18	I	I	1	1.266
0	18	M	M	1	1.8177
0	18	A	A	1	1.6413
0	18	N	N	1	1.7164
0	18	S	S	1	1.5612

0	18	R	R	1	1.9145
0	18	O	O	1	2.5065
0	18	U	U	1	1.8531
0	18	F	F	1	2.0919
0	18	D	D	1	1.885
0	18	W	W	1	2.1113
0	18	G	G	1	2.0953
0	18	K	K	1	2.0912
0	18	H	H	1	1.7595
0	18	B	B	1	1.9501
0	18	E	E	1	3.9718
0	18	T	T	1	1.7291
0	18	I	I	1	1.6909
0	18	M	M	1	2.2213
0	18	A	A	1	2.0576
0	18	N	N	1	1.8967
0	18	S	S	1	2.1231
0	18	R	R	1	2.1225
0	18	O	E	0	1.2264
0	18	U	T	0	0.88779
0	18	F	F	1	2.612
0	18	D	D	1	2.16
0	18	W	W	1	2.2997
0	18	G	G	1	2.1476
0	18	K	K	1	2.4304
0	18	E	E	1	2.3073
0	18	T	T	1	1.466
0	18	I	I	1	1.3949
0	18	M	N	0	1.581
0	18	A	A	1	1.5892
0	18	N	I	0	1.5404
0	18	S	S	1	1.4841
0	18	R	R	1	1.7033
0	18	O	S	0	1.748
0	18	U	U	1	2.0484
0	18	F	F	1	2.2018
0	18	D	D	1	1.816

0	18	W	U	0	1.9235
0	18	G	R	0	2.2111
0	18	K	K	1	2.4181
0	18	H	H	1	1.6953
0	18	B	B	1	2.0861
0	18	E	E	1	2.2883
0	18	T	E	0	6.161
0	18	I	I	1	2.3261
0	18	M	M	1	1.9446
0	18	A	A	1	2.5759
0	18	N	N	1	1.737
0	18	S	S	1	2.034
0	18	R	R	1	2.0917
0	18	O	O	1	2.3402
0	18	U	U	1	1.9552
0	18	F	H	0	2.3432
0	18	D	D	1	1.999
0	18	W	U	0	2.3684
0	17	E	E	1	2.6039
0	17	T	T	1	1.6803
0	17	I	I	1	1.3602
0	17	M	M	1	1.91
0	17	A	A	1	1.8231
0	17	N	N	1	1.5441
0	17	S	S	1	1.5791
0	17	R	R	1	1.8502
0	17	O	O	1	2.403
0	17	U	U	1	2.0204
0	17	F	F	1	2.0122
0	17	D	D	1	1.9414
0	17	W	W	1	1.9561
0	17	G	G	1	1.8025
0	17	K	K	1	2.0707
0	17	H	H	1	1.6445
0	17	B	B	1	1.9147
0	18	E	E	1	2.712
0	18	T	T	1	1.4899

0	18	I	I	1	1.4298
0	18	M	M	1	1.8983
0	18	A	A	1	1.6254
0	18	N	N	1	1.7148
0	18	S	I	0	1.563
0	18	R	R	1	1.9909
0	18	O	O	1	2.4546
0	18	U	U	1	1.8962
0	18	F	F	1	2.1815
0	18	D	D	1	2.1344
0	18	W	W	1	2.2342
0	18	G	G	1	2.24
0	18	K	T	0	1.3411
0	18	H	A	0	1.4678
0	18	B	B	1	2.6676
0	18	E	E	1	2.3025
0	18	T	T	1	1.2645
0	18	I	I	1	1.1347
0	18	M	N	0	1.5125
0	18	A	S	0	9.8487
0	18	N	E	0	0.87117
0	18	S	E	0	0.69313
0	18	R	E	0	0.6567
0	18	O	E	0	0.62811
0	18	U	E	0	0.59118
0	18	F	E	0	0.65879
0	18	D	E	0	0.6244
0	18	W	E	0	0.60928
0	18	G	E	0	0.66943
0	18	K	E	0	0.57112
0	18	H	E	0	0.65132
0	18	B	E	0	0.57363
0	18	J	E	0	0.62186
0	18	Q	E	0	0.521
0	18	V	E	0	0.61647
0	18	X	E	0	0.65856
0	18	Y	E	0	0.64284

0	18	Z	E	0	0.57397
0	18	C	E	0	0.62987
0	18	P	E	0	0.57793
0	18	L	E	0	0.31936
0	18	E	E	1	2.5789
0	18	T	E	0	0.74346
0	18	I	E	0	0.6611
0	18	M	E	0	0.66663
0	18	A	E	0	0.66679
0	18	N	E	0	0.68563
0	18	S	E	0	0.66858
0	18	R	E	0	0.65802
0	18	O	E	0	0.62582
0	18	U	E	0	0.62901
0	18	F	E	0	0.63846
0	18	D	E	0	0.60763
0	18	W	E	0	0.60529
0	18	G	E	0	0.49595
0	18	K	E	0	0.44653
0	18	H	I	0	2.4399
0	18	B	Not A Valid Character	0	0.37848
0	18	J	E	0	0.71531
0	18	Q	E	0	0.4606
0	18	V	E	0	0.55887
0	18	X	E	0	0.51016
0	18	Y	E	0	0.47372
0	18	Z	E	0	0.45229
0	18	C	E	0	0.49313
0	18	P	E	0	0.4785
0	18	L	E	0	0.29863
0	20	E	E	1	2.4766
0	20	T	T	1	1.6454
0	20	I	I	1	1.7435
0	20	M	M	1	2.257
0	20	A	A	1	1.9967
0	20	N	N	1	1.898

0	20	S	S	1	1.827
0	20	R	R	1	2.2322
0	20	O	O	1	2.9766
0	20	U	U	1	2.2617
0	20	F	F	1	2.5138
0	20	D	D	1	2.2789
0	20	W	W	1	2.2691
0	20	G	G	1	2.544
0	20	K	K	1	2.3408
0	51	E	E	1	5.298
0	51	T	I	0	5.5713
0	51	I	E	0	0.60797
0	51	M	A	0	4.5984
0	51	A	E	0	2.6
0	51	N	T	0	1.48
0	51	S	S	1	3.8421
0	51	R	R	1	3.6498
0	51	O	T	0	2.4482
0	51	U	M	0	1.4889
0	18	E	E	1	2.1831
0	18	T	T	1	2.2478
0	18	I	I	1	2.0555
0	18	M	M	1	2.8897
0	18	A	A	1	2.7571
0	18	N	N	1	2.2628
0	18	S	S	1	1.9911
0	18	R	R	1	2.6953
0	18	O	O	1	2.741
0	18	U	U	1	2.275
0	18	F	F	1	2.5925
0	18	D	N	0	2.0895
0	18	W	E	0	0.44687
0	18	G	Not A Valid Character	0	0.96647
0	18	K	D	0	2.3519
2	21	E	E	1	4.253
2	21	T	T	1	1.8669

2	21	I	I		1	1.63
2	21	M	A		0	1.9079
2	21	A	A		1	1.8204
2	21	N	A		0	2.0449
2	21	S	S		1	1.98
2	21	R	S		0	1.8013
2	21	O	K		0	2.0136
2	21	U	U		1	2.0721
2	21	F	H		0	2.6464
2	21	D	D		1	2.4589
2	21	W	S		0	2.5519
2	21	G	I		0	2.4277
12	18	E	T		0	3.5252
12	18	T	T		1	1.6856
12	18	I	M		0	2.0875
12	18	M	M		1	2.0803
12	18	A	M		0	1.871
12	18	N	N		1	2.0555
12	18	S	S		1	2.2903
12	18	R	A		0	2.0794
12	18	O	T		0	0.55693
12	18	U	T		0	1.088
12	18	F	I		0	0.95718
12	18	D	V		0	1.7019
12	18	W	I		0	0.74953
12	18	G	Not A Valid Character		0	2.1401
12	18	K	U		0	2.1546
12	18	H	H		1	1.9411
12	18	B		5	0	2.1168
12	18	E	E		1	2.6558
12	18	T	T		1	1.8058
12	18	I	I		1	1.3794
12	18	M	M		1	1.6903
12	18	A	A		1	1.5854
12	18	N	A		0	1.6351
12	18	S	S		1	1.5419

12	18	R	R		1	1.8458
12	18	O	O		1	2.0747
12	18	U	U		1	1.7295
12	18	F	F		1	1.9
12	18	D	D		1	1.7783
12	18	W	R		0	1.8769
12	18	G	D		0	1.8339
12	18	K	L		0	2.1291
12	18	H	H		1	1.7621
12	18	B	B		1	1.9838
12	18	E	E		1	2.4587
12	18	T	T		1	2.0109
12	18	I	I		1	1.8305
12	18	M	M		1	2.4631
12	18	A	A		1	2.5207
12	18	N	T		0	2.1835
12	18	S	E		0	0.46585
12	18	R	E		0	1.1472
12	18	O	N		0	1.5115
12	18	U	U		1	3.102
12	18	F		3	0	2.6378
12	18	D	D		1	2.4263
12	18	W	W		1	2.254
12	18	G	O		0	3.0236
12	18	K	K		1	2.9003
11	16	E	E		1	2.6398
11	16	T	T		1	4.7953
11	16	I	I		1	2.4079
11	16	M	M		1	2.4489
11	16	A	A		1	2.5784
11	16	N	N		1	2.0919
11	16	S	S		1	2.0267
11	16	R	R		1	2.6515
11	16	O	S		0	2.0925
11	16	U	U		1	2.6511
11	16	F	I		0	1.9634
11	16	D	T		0	0.90829

11	16	W	A	0	2.3171
12	18	E	Not A Valid Character	0	2.1164
12	18	T	T	1	1.7548
12	18	I	I	1	1.6298
12	18	M	M	1	2.0457
12	18	A	A	1	1.9297
12	18	N	N	1	2.0108
12	18	S	S	1	1.9866
12	18	R	R	1	2.1778
12	18	O	O	1	2.4674
12	18	U	U	1	2.2037
12	18	F	F	1	2.3812
12	18	D	D	1	2.0539
12	18	W	W	1	2.134
12	18	G	G	1	2.0935
12	18	K	K	1	2.4823
0	19	E	E	1	2.4339
0	19	T	T	1	2.0226
0	19	I	I	1	1.8932
0	19	M	I	0	1.7264
0	19	A	T	0	0.76452
0	19	N	N	1	2.2579
0	19	S	S	1	1.8313
0	19	R	K	0	2.5615
0	19	O	K	0	2.476
0	19	U	I	0	2.2298
0	19	F	T	0	1.0229
0	19	D	E	0	0.73387
0	19	W	I	0	1.3312
0	19	G	Not A Valid Character	0	2.1966
0	19	K	A	0	1.987
0	19	H	H	1	2.0136
0	19	B	B	1	3.0497
11	16	E	E	1	2.5949
11	16	T	T	1	1.9656
11	16	I	I	1	2.1896

11	16	M	A	0	2.5181
11	16	A	A	1	2.5227
11	16	N	N	1	1.9614
11	16	S	S	1	1.9378
11	16	R	S	0	2.3032
11	16	O	K	0	2.5553
11	16	U	U	1	2.6352
11	16	F	E	0	1.7266
11	16	D	E	0	0.47036
11	16	W	T	0	0.63852
11	16	G	M	0	3.47
11	16	K	E	0	0.53156
11	16	H	E	0	0.96193

Raw data file that records the user's age, grade, the letter they input and how long it took them to input something.

APPENDIX E – CODE USED IN PROJECT

M6.MLAPP

```
classdef M6 < matlab.apps.AppBase

    % Properties that correspond to app components
    properties (Access = public)
        UIFigure                        matlab.ui.Figure
        TabGroup                        matlab.ui.container.TabGroup
        InstructionsTab                 matlab.ui.container.Tab
        DASHLabel                       matlab.ui.control.Label
        Image3                          matlab.ui.control.Image
        DOTLabel                        matlab.ui.control.Label
        Image2                          matlab.ui.control.Image
        ThisistheMorseCodeTypingtestLabel  matlab.ui.control.Label
        PressToContinueButton           matlab.ui.control.Button
        TrialTab                        matlab.ui.container.Tab
        resultButton                    matlab.ui.control.Button
        trialInstruction                matlab.ui.control.Label
        YourInputLabel                  matlab.ui.control.Label
        morseInput                      matlab.ui.control.Label
        trialImage                      matlab.ui.control.Image
        LetsTryUsingBasicCharactersLabel  matlab.ui.control.Label
        InformationTab                  matlab.ui.container.Tab
        NotePut0asyourgradeifyouarenotinschoolLabel
matlab.ui.control.Label
        gradeInput                      matlab.ui.control.DropDown
        EnteryourGradeDropDownLabel  matlab.ui.control.Label
        ageInput                        matlab.ui.control.DropDown
        EnteryourAgeDropDownLabel    matlab.ui.control.Label
        StartGame                       matlab.ui.control.Button
        GameTab                         matlab.ui.container.Tab
        sLabel                          matlab.ui.control.Label
        Debug2                          matlab.ui.control.Label
        Debug1                          matlab.ui.control.Label
        Image                           matlab.ui.control.Image
        LetterInputDynamic              matlab.ui.control.Label
        LetterInputLabel                matlab.ui.control.Label
        MorseInputLabel                 matlab.ui.control.Label
        MorseInputDynamic               matlab.ui.control.Label
        Label                           matlab.ui.control.Label
        StatisticsTab                   matlab.ui.container.Tab
        CongratulationsonCompletingtheTypingTestLabel
matlab.ui.control.Label
        YourAverageSpeedinCharactersPerMinuteLabel
matlab.ui.control.Label
        YourAccuracyinageLabel          matlab.ui.control.Label
        averageSpeedOutput              matlab.ui.control.Label
        accuracyOutput                  matlab.ui.control.Label
```

```
        ClicktoContinueButton        matlab.ui.control.Button
        QRCodeTab                    matlab.ui.container.Tab
        LastContinueButton           matlab.ui.control.Button
        Image4                       matlab.ui.control.Image
        Label3                       matlab.ui.control.Label
        ThankYouforUsingtheMorseCodeTypingTestLabel
matlab.ui.control.Label
    end

    % Callbacks that handle component events
    methods (Access = private)

        % Button pushed function: StartGame
        function StartGameButtonPushed(app, event)
            app.TabGroup.SelectedTab = app.GameTab;
            tic

%           Takes the grade and age input from he user
            gradeInput = app.gradeInput.Value;
            ageInput = app.ageInput.Value;
%           Makes the timer label visible
            app.Label.Visible = 'on';

%           Initiates a timer object and displays the timer in the
right
%           corner of the game tab
            t = timer;
            t.Period = 1;
            t.ExecutionMode = 'fixedRate';
            t.TasksToExecute = 32;
            t.TimerFcn = @(~, thisEvent) timerLabel(app);
%           Starts the timer
            start(t);
%           Runs the function with the grade and age input as
parameters
            MorseKeyer7(app, gradeInput, ageInput);
%           Switches to the statistics tab after the game ends
            app.TabGroup.SelectedTab = app.StatisticsTab;
%           Resets the timer label to 30s
            app.Label.Text = "32";

        end

        % Callback function
        function ClicktoContinueButtonPushed(app, event)
%           Switches to the statistics tab after the
            app.TabGroup.SelectedTab = app.QRCodeTab;
%           Resets the defalut age and grade input values
            app.gradeInput.Value = 2;
            app.ageInput.Value = 7;

        end
```

```
        % Button pushed function: PressToContinueButton
        function PressToContinueButtonPushed(app, event)
%           Method invoked when the button is pressed on the first tab
%           which displays the information
            app.TabGroup.SelectedTab = app.TrialTab;
%           Runs the Morse Trial function which makes the user input a
dot
%           and dash
            MorseKeyerTrial2(app);
        end

        % Button pushed function: ClicktoContinueButton
        function ClicktoContinueButtonPushed2(app, event)
%           Switches to the QR Code tab after the click to continue
button
%           is pressed
            app.TabGroup.SelectedTab = app.QRCodeTab;
        end

        % Button pushed function: LastContinueButton
        function LastContinueButtonPushed(app, event)
%           Switches to the first tab again after the user is done with
%           playing the game
            app.TabGroup.SelectedTab = app.InstructionsTab;
        end
    end

    % Component initialization
    methods (Access = private)

        % Create UIFigure and components
        function createComponents(app)

            % Get the file path for locating images
            pathToMLAPP = fileparts(mfilename('fullpath'));

            % Create UIFigure and hide until all components are created
            app.UIFigure = uifigure('Visible', 'off');
            app.UIFigure.Position = [100 100 1601 1110];
            app.UIFigure.Name = 'MATLAB App';

            % Create TabGroup
            app.TabGroup = uitabgroup(app.UIFigure);
            app.TabGroup.Position = [27 23 1555 1064];

            % Create InstructionsTab
            app.InstructionsTab = uitab(app.TabGroup);
            app.InstructionsTab.Title = 'Instructions Tab';
            app.InstructionsTab.BackgroundColor = [0.9294 0.6941
0.1255];

            % Create PressToContinueButton
```

```
            app.PressToContinueButton = uibutton(app.InstructionsTab,
'push');
            app.PressToContinueButton.ButtonPushedFcn =
createCallbackFcn(app, @PressToContinueButtonPushed, true);
            app.PressToContinueButton.FontSize = 48;
            app.PressToContinueButton.FontWeight = 'bold';
            app.PressToContinueButton.Position = [698 191 439 86];
            app.PressToContinueButton.Text = 'Press To Continue';

            % Create ThisistheMorseCodeTypingtestLabel
            app.ThisistheMorseCodeTypingtestLabel =
uilabel(app.InstructionsTab);
            app.ThisistheMorseCodeTypingtestLabel.HorizontalAlignment =
'center';
            app.ThisistheMorseCodeTypingtestLabel.FontSize = 48;
            app.ThisistheMorseCodeTypingtestLabel.FontWeight = 'bold';
            app.ThisistheMorseCodeTypingtestLabel.Position = [120 694
1447 343];
            app.ThisistheMorseCodeTypingtestLabel.Text = {'Welcome to
the Morse Code Typing test!'; ''; 'A dot is a short press of the button
with a short pitched tone. '; 'A dash is a long press with a high
pitched tone. '; 'Click on the button below using the mouse to
continue.'};

            % Create Image2
            app.Image2 = uiimage(app.InstructionsTab);
            app.Image2.Position = [514 468 328 163];
            app.Image2.ImageSource = fullfile(pathToMLAPP, 'Images ',
'Dot.jpg');

            % Create DOTLabel
            app.DOTLabel = uilabel(app.InstructionsTab);
            app.DOTLabel.FontSize = 18;
            app.DOTLabel.FontWeight = 'bold';
            app.DOTLabel.Position = [656 415 44 24];
            app.DOTLabel.Text = 'DOT';

            % Create Image3
            app.Image3 = uiimage(app.InstructionsTab);
            app.Image3.Position = [978 456 319 188];
            app.Image3.ImageSource = fullfile(pathToMLAPP, 'Images ',
'Dash.jpg');

            % Create DASHLabel
            app.DASHLabel = uilabel(app.InstructionsTab);
            app.DASHLabel.FontSize = 18;
            app.DASHLabel.FontWeight = 'bold';
            app.DASHLabel.Position = [1122 415 56 24];
            app.DASHLabel.Text = 'DASH';

            % Create TrialTab
            app.TrialTab = uitab(app.TabGroup);
            app.TrialTab.Title = 'Trial';
```

```
            app.TrialTab.BackgroundColor = [0.9294 0.6941 0.1255];

            % Create LetsTryUsingBasicCharactersLabel
            app.LetsTryUsingBasicCharactersLabel =
uilabel(app.TrialTab);
            app.LetsTryUsingBasicCharactersLabel.FontSize = 48;
            app.LetsTryUsingBasicCharactersLabel.FontWeight = 'bold';
            app.LetsTryUsingBasicCharactersLabel.Position = [472 867
769 65];
            app.LetsTryUsingBasicCharactersLabel.Text = 'Let''s Try
Using Basic Characters';

            % Create trialImage
            app.trialImage = uiimage(app.TrialTab);
            app.trialImage.Position = [706 581 351 232];
            app.trialImage.ImageSource = fullfile(pathToMLAPP, 'Images
', 'Dot.jpg');

            % Create morseInput
            app.morseInput = uilabel(app.TrialTab);
            app.morseInput.FontSize = 48;
            app.morseInput.FontWeight = 'bold';
            app.morseInput.Position = [905 401 85 65];
            app.morseInput.Text = '';

            % Create YourInputLabel
            app.YourInputLabel = uilabel(app.TrialTab);
            app.YourInputLabel.FontSize = 48;
            app.YourInputLabel.Position = [645 395 239 64];
            app.YourInputLabel.Text = 'Your Input:';

            % Create trialInstruction
            app.trialInstruction = uilabel(app.TrialTab);
            app.trialInstruction.FontSize = 48;
            app.trialInstruction.Position = [467 511 1082 64];
            app.trialInstruction.Text = 'Press the red button for a
short while';

            % Create resultButton
            app.resultButton = uibutton(app.TrialTab, 'push');
            app.resultButton.FontSize = 48;
            app.resultButton.FontWeight = 'bold';
            app.resultButton.Position = [719 148 385 168];
            app.resultButton.Text = 'Input a Dot';

            % Create InformationTab
            app.InformationTab = uitab(app.TabGroup);
            app.InformationTab.Title = 'Information';
            app.InformationTab.BackgroundColor = [0.9294 0.6941
0.1255];

            % Create StartGame
            app.StartGame = uibutton(app.InformationTab, 'push');
```

```
            app.StartGame.ButtonPushedFcn = createCallbackFcn(app,
@StartGameButtonPushed, true);
            app.StartGame.FontSize = 48;
            app.StartGame.FontWeight = 'bold';
            app.StartGame.Position = [810 255 278 72];
            app.StartGame.Text = 'Start Game';

            % Create EnteryourAgeDropDownLabel
            app.EnteryourAgeDropDownLabel =
uilabel(app.InformationTab);
            app.EnteryourAgeDropDownLabel.HorizontalAlignment =
'right';
            app.EnteryourAgeDropDownLabel.FontSize = 48;
            app.EnteryourAgeDropDownLabel.Position = [669 630 328 64];
            app.EnteryourAgeDropDownLabel.Text = 'Enter your Age';

            % Create ageInput
            app.ageInput = uidropdown(app.InformationTab);
            app.ageInput.Items = {'7', '8', '9', '10', '11', '12',
'13', '14', '15', '16', '17', '18', '19', '20', '21', '22', '23', '24',
'25', '26', '27', '28', '29', '30', '31', '32', '33', '34', '35', '36',
'37', '38', '39', '40', '41', '42', '43', '44', '45', '46', '47', '48',
'49', '50', '51', '52', '53', '54', '55', '56', '57', '58', '59', '60',
'61', '62', '63', '64', '65', '66', '67', '68', '69', '70', '71', '72',
'73', '74', '75', '76', '77', '78', '79', '80'};
            app.ageInput.FontSize = 48;
            app.ageInput.Position = [1012 633 97 61];
            app.ageInput.Value = '7';

            % Create EnteryourGradeDropDownLabel
            app.EnteryourGradeDropDownLabel =
uilabel(app.InformationTab);
            app.EnteryourGradeDropDownLabel.HorizontalAlignment =
'right';
            app.EnteryourGradeDropDownLabel.FontSize = 48;
            app.EnteryourGradeDropDownLabel.Position = [615 529 377
64];
            app.EnteryourGradeDropDownLabel.Text = 'Enter your Grade';

            % Create gradeInput
            app.gradeInput = uidropdown(app.InformationTab);
            app.gradeInput.Items = {'2', '3', '4', '5', '6', '7', '8',
'9', '10', '11', '12', '0'};
            app.gradeInput.FontSize = 48;
            app.gradeInput.Position = [1007 532 102 61];
            app.gradeInput.Value = '2';

            % Create NotePut0asyourgradeifyouarenotinschoolLabel
            app.NotePut0asyourgradeifyouarenotinschoolLabel =
uilabel(app.InformationTab);

app.NotePut0asyourgradeifyouarenotinschoolLabel.HorizontalAlignment =
'center';
```

```
            app.NotePut0asyourgradeifyouarenotinschoolLabel.FontSize =
48;
            app.NotePut0asyourgradeifyouarenotinschoolLabel.FontWeight
= 'bold';
            app.NotePut0asyourgradeifyouarenotinschoolLabel.Position =
[370 402 1146 65];
            app.NotePut0asyourgradeifyouarenotinschoolLabel.Text =
'Note: Put 0 as your grade if you are not in school';

            % Create GameTab
            app.GameTab = uitab(app.TabGroup);
            app.GameTab.Title = 'Game';
            app.GameTab.BackgroundColor = [0.9294 0.6941 0.1255];

            % Create Label
            app.Label = uilabel(app.GameTab);
            app.Label.FontSize = 48;
            app.Label.Visible = 'off';
            app.Label.Position = [1436 813 59 64];
            app.Label.Text = '32';

            % Create MorseInputDynamic
            app.MorseInputDynamic = uilabel(app.GameTab);
            app.MorseInputDynamic.FontSize = 48;
            app.MorseInputDynamic.FontWeight = 'bold';
            app.MorseInputDynamic.Position = [838 470 518 65];
            app.MorseInputDynamic.Text = '';

            % Create MorseInputLabel
            app.MorseInputLabel = uilabel(app.GameTab);
            app.MorseInputLabel.FontSize = 48;
            app.MorseInputLabel.Position = [499 470 266 64];
            app.MorseInputLabel.Text = 'Morse Input';

            % Create LetterInputLabel
            app.LetterInputLabel = uilabel(app.GameTab);
            app.LetterInputLabel.FontSize = 48;
            app.LetterInputLabel.Position = [508 402 254 64];
            app.LetterInputLabel.Text = 'Letter Input';

            % Create LetterInputDynamic
            app.LetterInputDynamic = uilabel(app.GameTab);
            app.LetterInputDynamic.FontSize = 48;
            app.LetterInputDynamic.FontWeight = 'bold';
            app.LetterInputDynamic.Position = [837 404 503 65];
            app.LetterInputDynamic.Text = '';

            % Create Image
            app.Image = uiimage(app.GameTab);
            app.Image.Position = [480 533 756 343];
            app.Image.ImageSource = fullfile(pathToMLAPP, 'Images ',
'E.jpg');
```

```
            % Create Debug1
            app.Debug1 = uilabel(app.GameTab);
            app.Debug1.Position = [1436 738 58 22];

            % Create Debug2
            app.Debug2 = uilabel(app.GameTab);
            app.Debug2.Position = [1436 685 41 22];
            app.Debug2.Text = 'Label2';

            % Create sLabel
            app.sLabel = uilabel(app.GameTab);
            app.sLabel.FontSize = 36;
            app.sLabel.Position = [1493 817 25 49];
            app.sLabel.Text = 's';

            % Create StatisticsTab
            app.StatisticsTab = uitab(app.TabGroup);
            app.StatisticsTab.Title = 'Statistics';
            app.StatisticsTab.BackgroundColor = [0.9294 0.6941 0.1255];

            % Create ClicktoContinueButton
            app.ClicktoContinueButton = uibutton(app.StatisticsTab,
'push');
            app.ClicktoContinueButton.ButtonPushedFcn =
createCallbackFcn(app, @ClicktoContinueButtonPushed2, true);
            app.ClicktoContinueButton.FontSize = 48;
            app.ClicktoContinueButton.FontWeight = 'bold';
            app.ClicktoContinueButton.Position = [724 152 418 72];
            app.ClicktoContinueButton.Text = 'Click to Continue';

            % Create accuracyOutput
            app.accuracyOutput = uilabel(app.StatisticsTab);
            app.accuracyOutput.FontSize = 48;
            app.accuracyOutput.Position = [1185 432 363 64];
            app.accuracyOutput.Text = '';

            % Create averageSpeedOutput
            app.averageSpeedOutput = uilabel(app.StatisticsTab);
            app.averageSpeedOutput.FontSize = 48;
            app.averageSpeedOutput.Position = [1184 493 383 64];
            app.averageSpeedOutput.Text = '';

            % Create YourAccuracyinageLabel
            app.YourAccuracyinageLabel = uilabel(app.StatisticsTab);
            app.YourAccuracyinageLabel.FontSize = 48;
            app.YourAccuracyinageLabel.Position = [622 432 530 64];
            app.YourAccuracyinageLabel.Text = 'Your Accuracy in %age:';

            % Create YourAverageSpeedinCharactersPerMinuteLabel
            app.YourAverageSpeedinCharactersPerMinuteLabel =
uilabel(app.StatisticsTab);
            app.YourAverageSpeedinCharactersPerMinuteLabel.FontSize =
48;
```

```
            app.YourAverageSpeedinCharactersPerMinuteLabel.Position =
[159 496 1027 64];
            app.YourAverageSpeedinCharactersPerMinuteLabel.Text = 'Your
Average Speed in Characters Per Minute:';

            % Create CongratulationsonCompletingtheTypingTestLabel
            app.CongratulationsonCompletingtheTypingTestLabel =
uilabel(app.StatisticsTab);
            app.CongratulationsonCompletingtheTypingTestLabel.FontSize
= 48;

app.CongratulationsonCompletingtheTypingTestLabel.FontWeight = 'bold';
            app.CongratulationsonCompletingtheTypingTestLabel.Position
= [296 865 1145 65];
            app.CongratulationsonCompletingtheTypingTestLabel.Text =
'Congratulations on Completing the Typing Test!!!';

            % Create QRCodeTab
            app.QRCodeTab = uitab(app.TabGroup);
            app.QRCodeTab.Title = 'QR Code ';
            app.QRCodeTab.BackgroundColor = [0.9294 0.6941 0.1255];

            % Create ThankYouforUsingtheMorseCodeTypingTestLabel
            app.ThankYouforUsingtheMorseCodeTypingTestLabel =
uilabel(app.QRCodeTab);
            app.ThankYouforUsingtheMorseCodeTypingTestLabel.FontSize =
48;
            app.ThankYouforUsingtheMorseCodeTypingTestLabel.FontWeight
= 'bold';
            app.ThankYouforUsingtheMorseCodeTypingTestLabel.Position =
[224 909 1158 65];
            app.ThankYouforUsingtheMorseCodeTypingTestLabel.Text =
'Thank You for Using the Morse Code Typing Test!';

            % Create Label3
            app.Label3 = uilabel(app.QRCodeTab);
            app.Label3.HorizontalAlignment = 'center';
            app.Label3.FontSize = 36;
            app.Label3.Position = [26 228 1550 576];
            app.Label3.Text = {'We would appreciate it if you could
fill out a form so that we can improve this device and app.'; ''; '';
''; ''; ''; ''; ''; ''; ''; ''; ''; 'You can scan the QR Code above using
your phone to go to the form.'};

            % Create Image4
            app.Image4 = uiimage(app.QRCodeTab);
            app.Image4.Position = [482 310 684 417];
            app.Image4.ImageSource = fullfile(pathToMLAPP, 'Images ',
'QRCode Final.png');

            % Create LastContinueButton
            app.LastContinueButton = uibutton(app.QRCodeTab, 'push');
```

```
            app.LastContinueButton.ButtonPushedFcn =
createCallbackFcn(app, @LastContinueButtonPushed, true);
            app.LastContinueButton.FontSize = 48;
            app.LastContinueButton.FontWeight = 'bold';
            app.LastContinueButton.Position = [583 126 418 81];
            app.LastContinueButton.Text = 'Click to Continue';

            % Show the figure after all components are created
            app.UIFigure.Visible = 'on';
        end
    end

    % App creation and deletion
    methods (Access = public)

        % Construct app
        function app = M6

            % Create UIFigure and components
            createComponents(app)

            % Register the app with App Designer
            registerApp(app, app.UIFigure)

            if nargout == 0
                clear app
            end
        end

        % Code that executes before app deletion
        function delete(app)

            % Delete UIFigure when app is deleted
            delete(app.UIFigure)
        end
    end
end
```

ARDUINO CODE

```
//Game1.ino
//Originally made by Vladimir Krsmanovic
//Modified by Aryan Kalaskar to include LEDs, a button and a buzzer. Other
//modifications include changes in the logic and code to input only a single
//instead of inputting a series of letters.
//Takes input from a button and translates the morse code to English words.
//Thank you to Vladimir Krsmanovic for making the code available to everyone.
```

```
//Thank you to Prof. Brian O'Connell for reviewing and suggesting changes to be
//made in the code.

const int buttonPin = 13;
const int buzzer = 9;

int ledState = HIGH;
int buttonState = LOW;
int lastButtonState = LOW;
int doesitwork = LOW;  // variable used for debuging early versions of the code

int pause_value = 100;  // depending on your skill and how fast your fingers
are you can change this value to make typing a message faster or slower
long signal_length = 0;
long pause = 0;

String morse = "";
String dash = "-";
String dot = "*";

boolean cheker = false;
boolean linecheker = false;

long lastDebounceTime = 0;
long debounceDelay = 50;
void setup()
{
  Serial.begin(9600);

  pinMode(buttonPin, INPUT);
  pinMode(ledPin, OUTPUT);
  pinMode(buzzer, OUTPUT);


  while(!digitalRead(buttonPin))
    ;

}

void loop() {

  buttonState = digitalRead(buttonPin);
```

```
  if (buttonState && lastButtonState)       // basic state machine depending on
the state of the signal from the button
  {
    ++signal_length;
    if (signal_length<2*pause_value)        //this help to notice that there is
a change in the signal length aka that its not a dot anymore but a dash
    {                                       // best use for the measuring of
signal_length would be use of the millis() but this was used  for simplicity
    tone(buzzer, 1500) ;
    digitalWrite(2,HIGH);
    }
    else
    {
      tone(buzzer, 1000) ;
      digitalWrite(3,HIGH);
      digitalWrite(4,HIGH);
      digitalWrite(5,HIGH);
      }
  }

  else if(!buttonState && lastButtonState)          //this part of the code
happens when the button is released and it send either * or - into the buffer
  {

     if (signal_length>50 && signal_length<2*pause_value )
     {
       morse =  morse + dot;
     }
      else if (signal_length>2*pause_value)
      {
        morse = morse +  dash;
      }
    signal_length=0;
    digitalWrite(13, LOW);
    noTone(buzzer);
  }
  else if(buttonState && !lastButtonState)          // this part happens when
the button is pressed and its use to reset several values
  {
    pause=0;
    digitalWrite(13, HIGH);
    cheker = true;
    linecheker = true;
  }
  else if (!buttonState && !lastButtonState)
```

```
  {
    ++pause;
    if (( pause>3*pause_value ) && (cheker))
    {
      printaj(morse);
      cheker = false;
      morse = "";
    }
    if ((pause>15*pause_value) && (linecheker))
    {
      linecheker = false;
    }
  }
  lastButtonState=buttonState;
  delay(1);
  digitalWrite(2,LOW);
  digitalWrite(3,LOW);
  digitalWrite(4,LOW);
  digitalWrite(5,LOW);
}
void printaj(String prevodilac)   //ugly part of the code but it works fine
{                                 //compare morse string to known morse values
and print out the letter or a number
                                  //the code is written based on the
international morse code, one thing i changed is that instead of typing a
special string to end the line it happens with enough delay
  if (prevodilac=="*-")
    Serial.print("A");
  else if (prevodilac=="-***")
    Serial.print("B");
  else if (prevodilac=="-*-*")
    Serial.print("C");
  else if (prevodilac=="-**")
    Serial.print("D");
  else if (prevodilac=="*")
    Serial.print("E");
  else if (prevodilac=="**-*")
    Serial.print("F");
  else if (prevodilac=="--*")
    Serial.print("G");
  else if (prevodilac=="****")
    Serial.print("H");
  else if (prevodilac=="**")
    Serial.print("I");
  else if (prevodilac=="*---")
```

```
    Serial.print("J");
  else if (prevodilac=="-*-")
    Serial.print("K");
  else if (prevodilac=="*-**")
    Serial.print("L");
  else if (prevodilac=="--")
    Serial.print("M");
  else if (prevodilac=="-*")
    Serial.print("N");
  else if (prevodilac=="---")
    Serial.print("O");
  else if (prevodilac=="*--*")
    Serial.print("P");
  else if (prevodilac=="--*-")
    Serial.print("Q");
  else if (prevodilac=="*-*")
    Serial.print("R");
  else if (prevodilac=="***")
    Serial.print("S");
  else if (prevodilac=="-")
    Serial.print("T");
  else if (prevodilac=="**-")
    Serial.print("U");
  else if (prevodilac=="***-")
    Serial.print("V");
  else if (prevodilac=="*--")
    Serial.print("W");
  else if (prevodilac=="-**-")
    Serial.print("X");
  else if (prevodilac=="-*--")
    Serial.print("Y");
  else if (prevodilac=="--**")
    Serial.print("Z");

  else if (prevodilac=="*----")
    Serial.print("1");
  else if (prevodilac=="**---")
    Serial.print("2");
  else if (prevodilac=="***--")
    Serial.print("3");
  else if (prevodilac=="****-")
    Serial.print("4");
  else if (prevodilac=="*****")
    Serial.print("5");
  else if (prevodilac=="-****")
```

```
    Serial.print("6");
  else if (prevodilac=="--***")
    Serial.print("7");
  else if (prevodilac=="---**")
    Serial.print("8");
  else if (prevodilac=="----*")
    Serial.print("9");
  else if (prevodilac=="-----")
    Serial.print("0");
  else
    Serial.print("Not A Valid Character");

  Serial.println();
  Serial.print(prevodilac);
  Serial.println();

  prevodilac="";
}
```

MORSEKEYERTRIAL2.M

```
% MorseKeyerTrial V2
% A.Kalaskar
% This fuction is used in the trial tab to let the user understand what
a
% dot and dash is. The function does not stop until the user inputs the
% right characters and follows the instructions. First, the function
% requires the user to input a dot correctly, following which it makes
the
% user enter a dash correctly.
% Thank you to Prof. Brian O'Connell for the help with the serial
% communication code and debugging.


function MorseKeyerTrial2 (app)


% Establishes the arduino object
X = serialportlist;
Port = X(end);
arduinoObj = serialport(Port,9600);


%% Code provided by Prof.O'Connell
% Configure the terminator, so that the feed recognizes a carriage
return

% as the end of a line. So everytime you use Serial.println() in the

% arduino, that will queue up a new line on the serial buffer

configureTerminator(arduinoObj,"CR/LF");

% Readline reads the next line and you could possibly have a few so
you'll

% want to use flush to clear it so you're just waiting for the next

% character

flush(arduinoObj);



%% Begins two infinite loops that end only if the user inputs the two
basic
%% characters, first the dot and then the dash, correctly.

% Loop for the dot input
while 1

    % Read that from the serial monitor
```

```
    y1 = readline(arduinoObj);% Reads the translated letter
    y2 = readline(arduinoObj);% Reads the morse code



%   If the input is a dot then indicate that the input is correct and
break
%   from this loop. Else, prompt the user to try again.
    if strcmp(y2, "*") == 1
%       Let user know that the input is correct and changes the image
to
%       an image of a dash.
        app.morseInput.Text = y2;
        app.trialImage.ImageSource = 'Images /Dash.jpg';
        app.resultButton.BackgroundColor = 'g';
        app.resultButton.Text = 'Correct!';
        pause(0.5);
        app.morseInput.Text = "";

%       Reset the button attributes
        app.resultButton.Text = 'Input the Dash';
        app.resultButton.BackgroundColor = [0.96 0.96 0.96];
        app.trialImage.ImageSource = 'Images /Dash.jpg';
%       Break out of the first loop if the input is correct
        break;
    else
%       Indicate that the input is wrong and prompts the user to try
again
        app.morseInput.Text = y2;
        app.resultButton.BackgroundColor = 'r';
        app.resultButton.Text = 'Try Again';
        pause(0.5);
        app.morseInput.Text = "";
%       Reset the button attributes
        app.resultButton.Text = 'Input the Dot';
        app.resultButton.BackgroundColor = [0.96 0.96 0.96];
    end

end

app.trialInstruction.Text = 'Now Press the Red Button for a long
while';


% Loop for the dash input
while 1

%   Reads the inputs from the serial monitor
    y1 = readline(arduinoObj);% Reads the translated letter
    y2 = readline(arduinoObj);% Reads the morse code
```

```
%   If the input is a dash then indicate that the input is correct and
break
%   from this loop. Else, prompt the user to try again.

    if strcmp(y2, "-") == 1
%       Let user know that the input is correct and resets the image to
%       an image of a dot.
        app.morseInput.Text = y2;
        app.resultButton.BackgroundColor = 'g';
        app.resultButton.Text = 'Correct!';
        pause(0.5);
        app.morseInput.Text = "";
        app.TabGroup.SelectedTab = app.InformationTab;
        app.resultButton.Text = 'Input the Dot';
        app.trialInstruction.Text = 'Press the red button for a short
while';
        app.trialImage.ImageSource = 'Images /Dot.jpg';
        app.resultButton.BackgroundColor = [0.96 0.96 0.96];
        break;
    else
%       Indicate that the input is wrong and prompts the user to try
again
        app.morseInput.Text = y2;
        app.resultButton.BackgroundColor = 'r';
        app.resultButton.Text = 'Try Again';
        pause(0.5);
        app.morseInput.Text = "";
%       Reset the button attributes
        app.resultButton.Text = 'Input the Dot';
        app.resultButton.BackgroundColor = [0.96 0.96 0.96];
    end

end

end
```

MORSEKEYER7

```
% Morse Keyer Function V7
% A.Kalaskar
% Made to read the serial monitor of the arduino circuit with code
% uploaded to facilitate one way communication and translation of morse
% code to the serial monitor using a button in the circuit.
Additionally,
% this function enables data collection and writes the data to a csv
file.
% Made for Team Chimera
% Thank you to Prof. Brian O'Connell for the help with the serial
% communication code and debugging.

function MorseKeyer7 (app, gradeInp, ageInp)



% Establishes the arduino object
X = serialportlist;
Port = X(end);
arduinoObj = serialport(Port,9600);


% Declares the variables
sumtimes = 0; % For the timer
correctCounter = 0; % For the number of correct letters inputted. Will
be
% used to calculate user accuracy
rightWrong = 0; % To add to the table, 0 for
DT = table; % Table that will be modified during the code run and will
be
% written to the csv file.

% An array of the letters listed in an order of increasing morse code
% complexity
correctLetterList =
["E","T","I","M","A","N","S","R","O","U","F","D","W","G","K","H","B","J
","Q","V","X","Y","Z","C","P","L"];


%% Code provided by Prof.O'Connell
% Essentially allowing MATLAB to listen to the Arduino serial monitor
pause(0.05); % allow time to establish the object


% Configure the terminator, so that the feed recognizes a carriage
return
% as the end of a line. So everytime you use Serial.println() in the
% arduino, that will queue up a new line on the serial buffer

configureTerminator(arduinoObj,"CR/LF");
```

```
% Readline reads the next line and you could possibly have a few so
you'll
% want to use flush to clear it so you're just waiting for the next

% character
flush(arduinoObj);

% So assuming you're looking for a 5 letter word
iter = 1; % This variable serves the purpose of an iterator counter
which
% helps in cycling through each expected character.
% Cycle through each expected character



%% Goes through each iteration for each letter in the correctLetterList
% array and checks whether the letter inputted is correct or no.

% While the iteration is less than 27 and the timer label text is not
equal
% to 0(indicating that the time has elapsed)
while iter < 27 && strcmp(app.Label.Text,"0") ~= 1
%   Begin a secondary timer
    tic

%   Read that from the serial monitor and load into an array
    y1 = readline(arduinoObj);% Reads the translated letter
    y2 = readline(arduinoObj);% Reads the morse code

%   Used in initial testing to test output
    app.Debug1.Text = "";
    app.Debug2.Text = "";

%   Included to avoid glitches and long response times
    if(strcmp(y1, " ") == 1)
        break;
    end

    disp(y1); % For reference
    disp(y2); % For reference

    % letter input in morse code

    % Used for time elapsed
    sumtimes = sumtimes + toc;

%   Based on the iterator variable, the image changes and the input is
%   displayed on the game tab. This is done using switch and case
%   statements on the iterator variable.
%   For each iteration of the loop, the image changes and the command
line
%   is read again to display on the app. The 0.2s pause is included to
give
```

```
%   a gap of 0.2s before the next letter pops up on the screen.
    switch(iter)
        case 1
            app.Image.ImageSource = 'Images /E.jpg';
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /T.jpg';

        case 2
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /I.jpg';


        case 3
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /M.jpg';


        case 4
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /A.jpg';

        case 5
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /N.jpg';

        case 6
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /S.jpg';


        case 7
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
```

```
            app.Image.ImageSource = 'Images /R.jpg';


        case 8
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /O.jpg';

        case 9
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /U.jpg';

        case 10
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /F.jpg';
        case 11
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /D.jpg';

        case 12
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /W.jpg';

        case 13
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /G.jpg';

        case 14
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /K.jpg';

        case 15
            app.LetterInputDynamic.Text = y1;
```

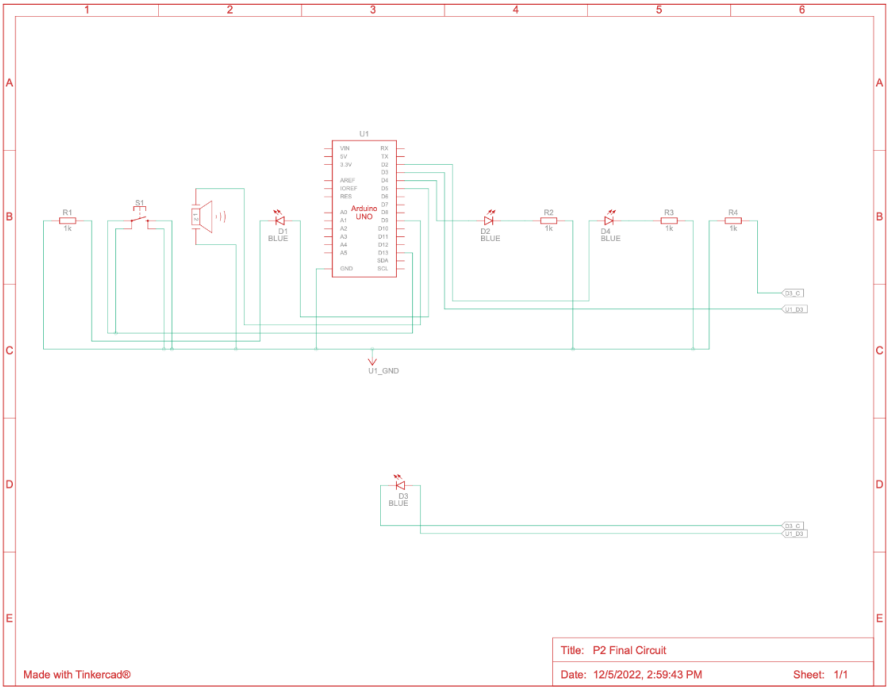
```
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /H.jpg';

        case 16
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /B.jpg';

        case 17
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /J.jpg';

        case 18
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /Q.jpg';

        case 19
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /V.jpg';

        case 20
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /X.jpg';

        case 21
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /Y.jpg';

        case 22
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /Z.jpg';
```

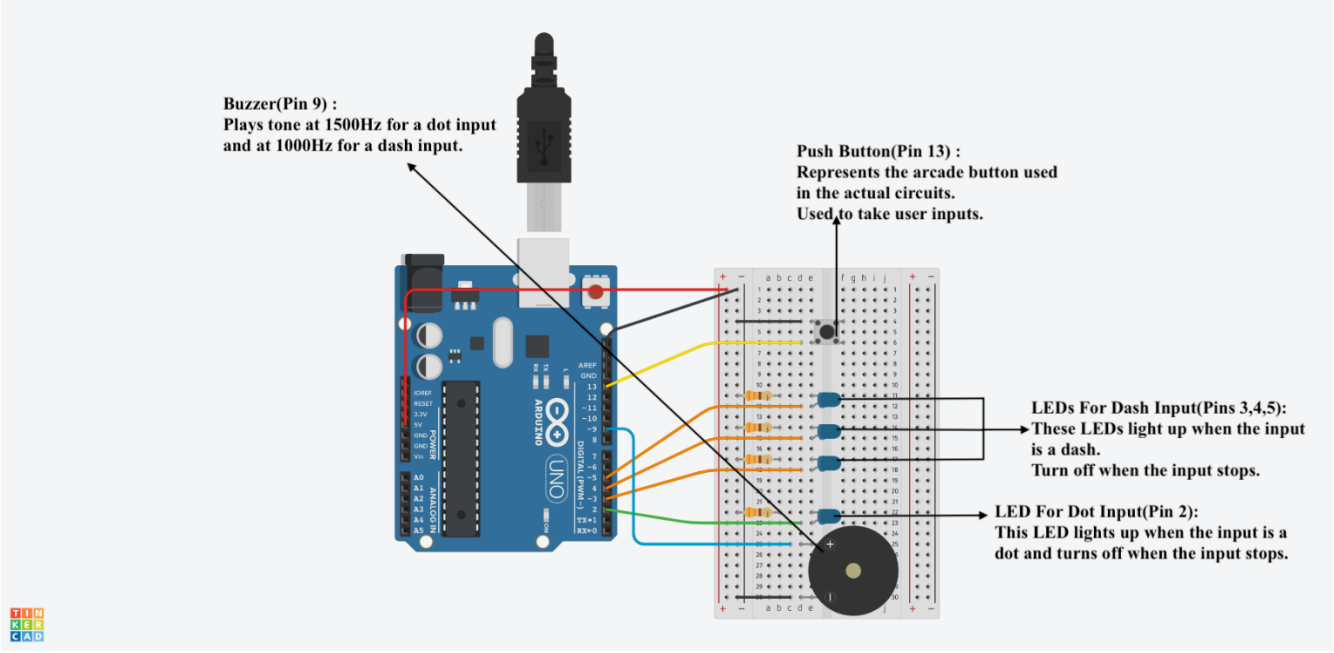
```
        case 23
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /C.jpg';

        case 24
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /P.jpg';

        case 25
            app.LetterInputDynamic.Text = y1;
            app.MorseInputDynamic.Text = y2;
            pause(0.2);app.LetterInputDynamic.Text =
"";app.MorseInputDynamic.Text = "";
            app.Image.ImageSource = 'Images /L.jpg';
    end
%       For each iteration of the loop, the rightwrong variable is set
to 0
%       if the letter inputted was wrong and 1 if it was right.
        if strcmp(correctLetterList(iter),y1)
            correctCounter = correctCounter+1;
            rightwrong = 1;
        else
            rightwrong = 0;
        end
%   addTable is a single row table that contains the data of one
%   iteration.
%   Horizontal concatenation of the the table:
    addTable = array2table([gradeInp, ageInp, correctLetterList(iter),
y1, rightwrong, toc]);
%   DT is the table that will be appended to the existing spreadsheet.
%   Vertical concatenation of addTable to the existing table of data of
the
%   user inputs:
    DT = [DT ; addTable];

%   Increment the iterator by one
    iter = iter+1;

end



%% This portion of the code deals with table appending and data
management

% Displays DT in the command line for reference
```

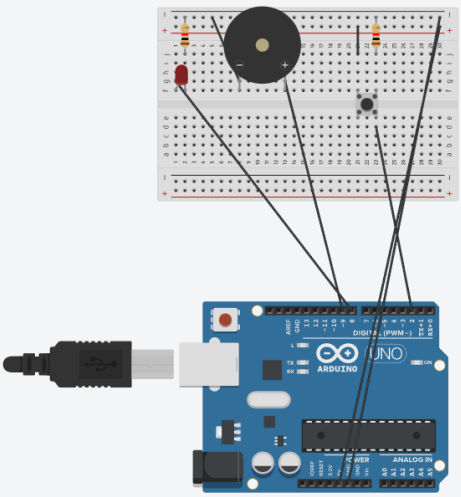
```
disp(DT);

% Stores the existing spreadsheet to a variable as a table
x = readtable('rough5.csv');

% Existing table appended with the new user's data is is stored in the
% existing addTable variable.
addTable = [x;DT];

% Writes the table to the csv file to update the data
writetable(addTable, 'rough5.csv');

% Resets the image in the Game Tab.
app.Image.ImageSource = 'Images /E.jpg';


% Calculates and displays the user's accuracy and speed in characters
per
% minute
accuracy = correctCounter/height(DT)*100;
app.accuracyOutput.Text = sprintf('%.2f', accuracy);
wpm = height(DT)*2;
app.averageSpeedOutput.Text = sprintf('%d', wpm);



end
```

APPENDIX F – WIRE DIAGRAMS FOR SPARKFUN BOARDS

FINAL ITERATION OF ELECTRONICS






ARDUINO
UNO

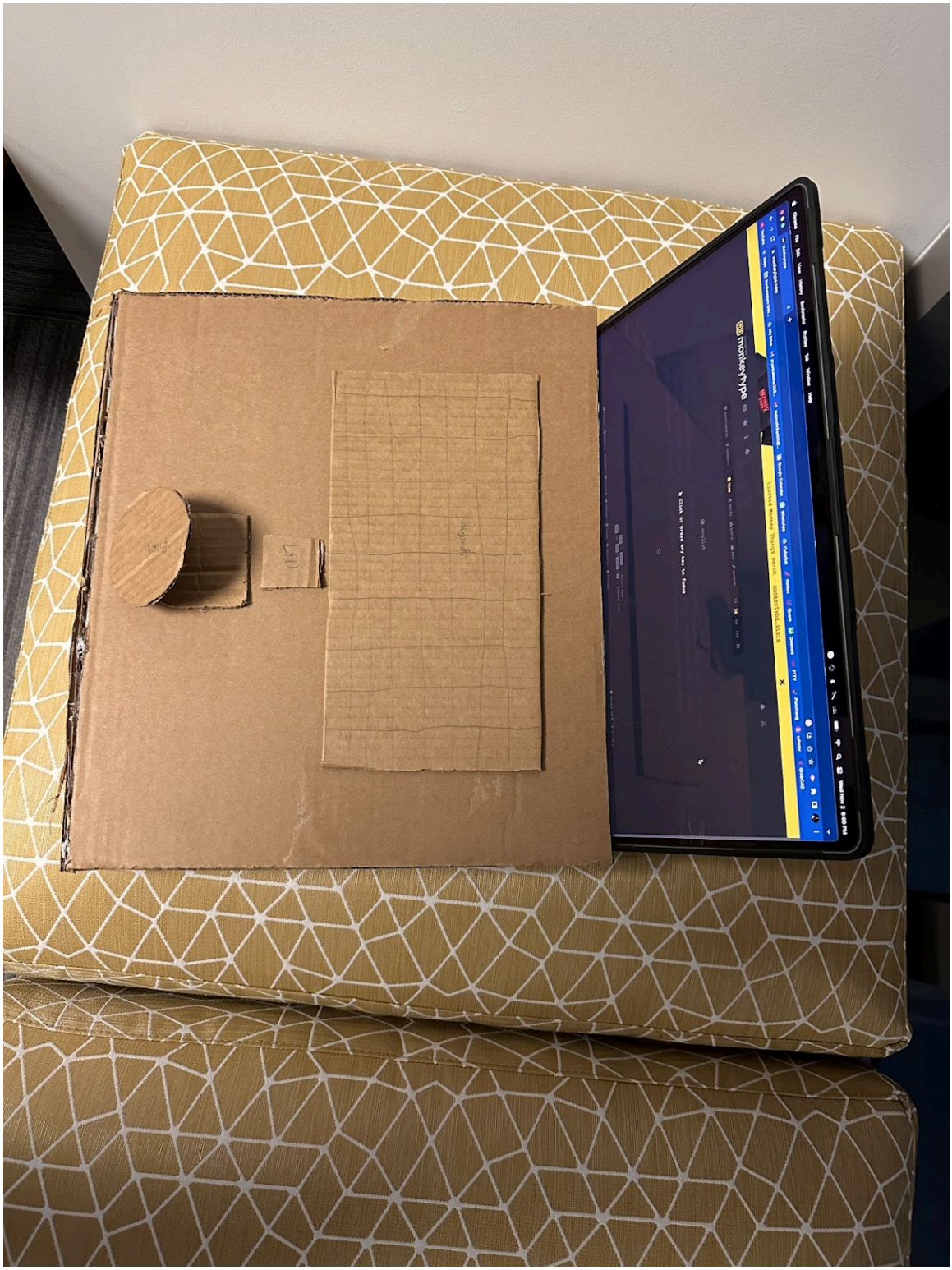
APPENDIX G – PHOTO LOG

CARDBOARD PROTOTYPE

C-1

Cardboard Prototype of the console with place holders for a button LEDs, buzzer and keyboard. Using a laptop to showcase that it would fit a 16in laptop.

C-2



Top view of cardboard prototype

C-3

Side view of the cardboard prototype

C-4

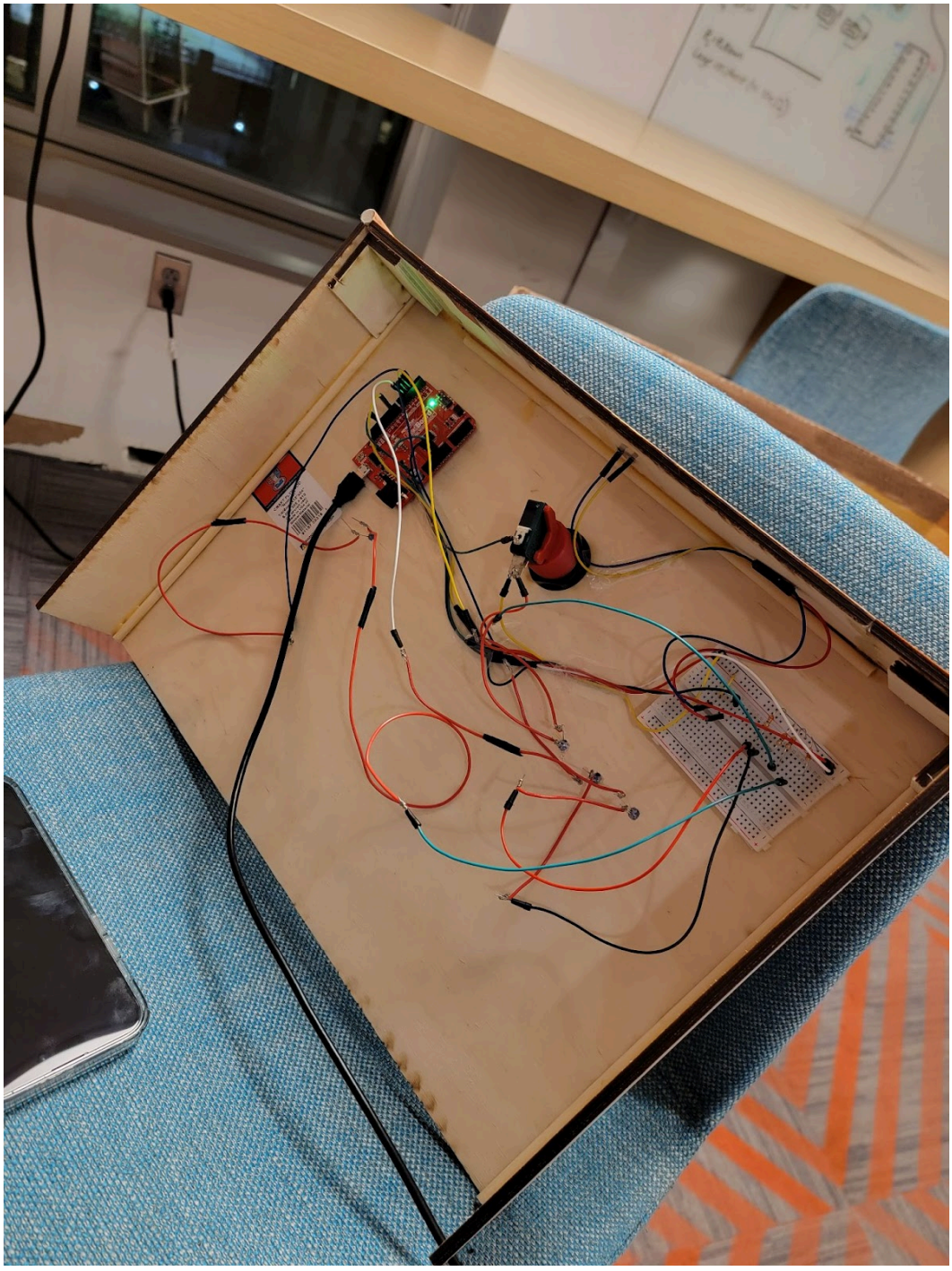
Placeholder spots for the red board and breadboard and to represent that the electronics will be located on the underside of the console.

C-5

The cardboard prototype in its transport configuration with the laptop underneath it

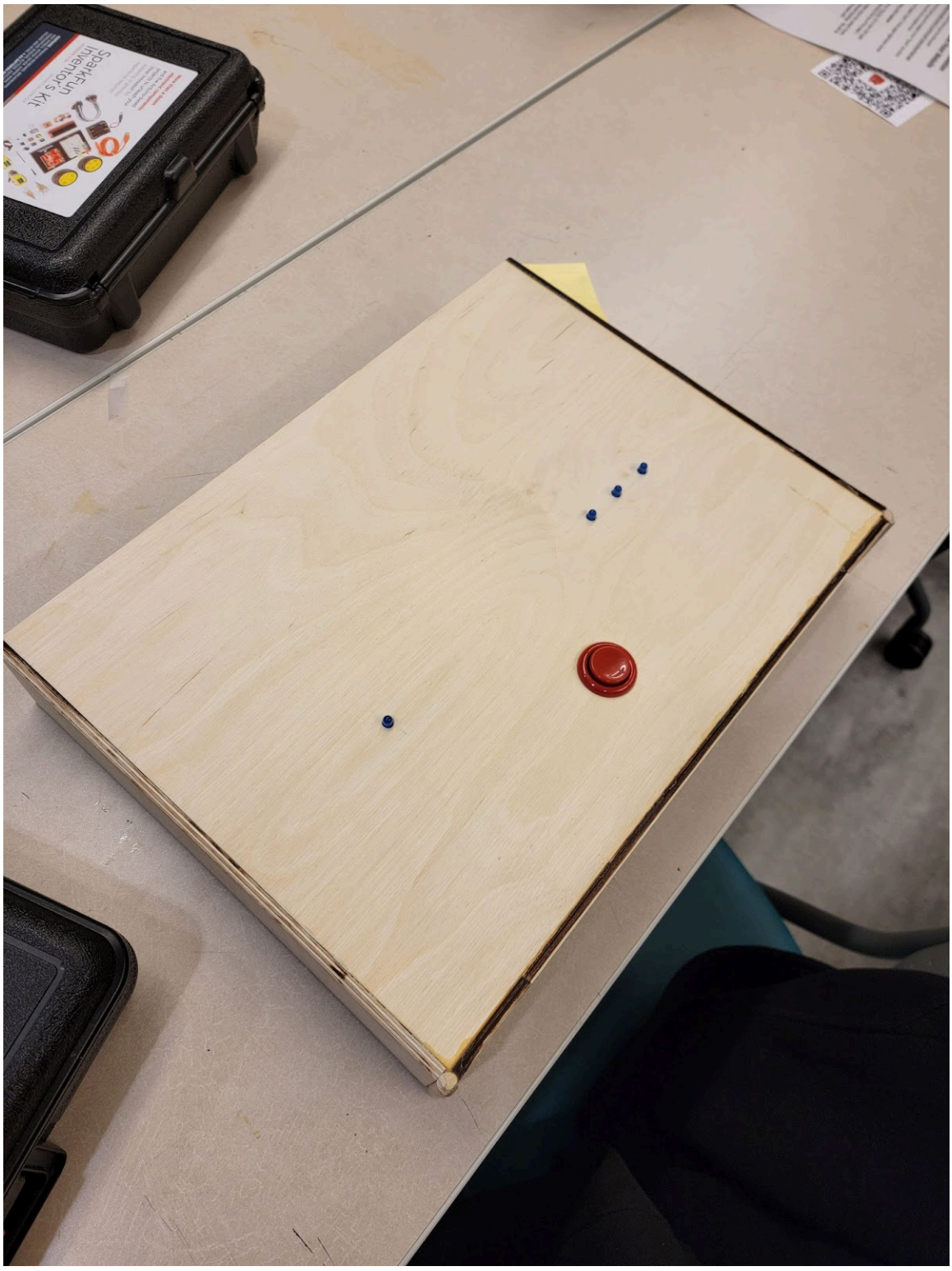
C-6

Another view of the cardboard prototype in its transport configuration, but with the laptop sticking out.



The electronics for the console set in place.

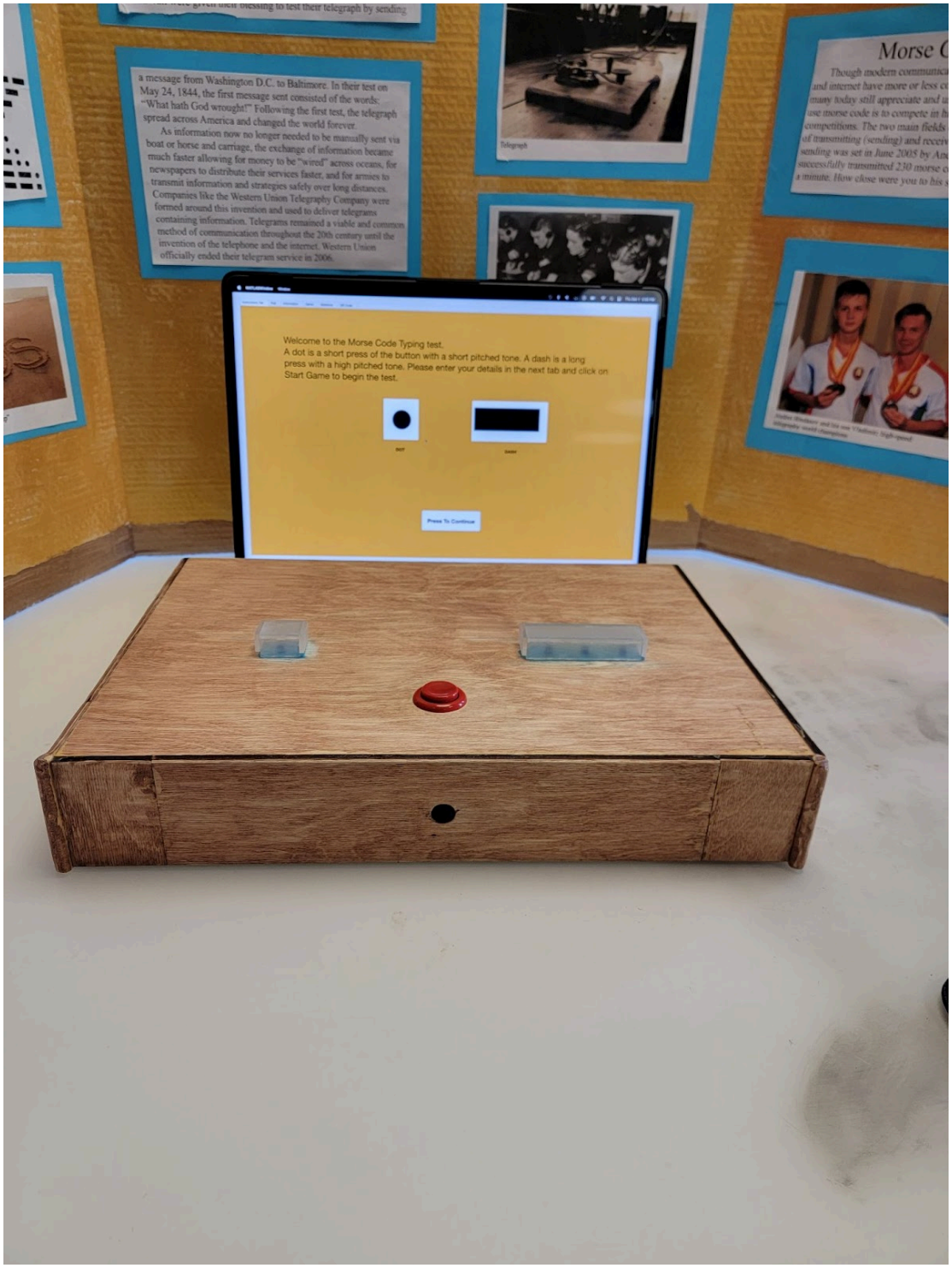
Initial stages of the whole exhibit with the poster vastly without any informational text



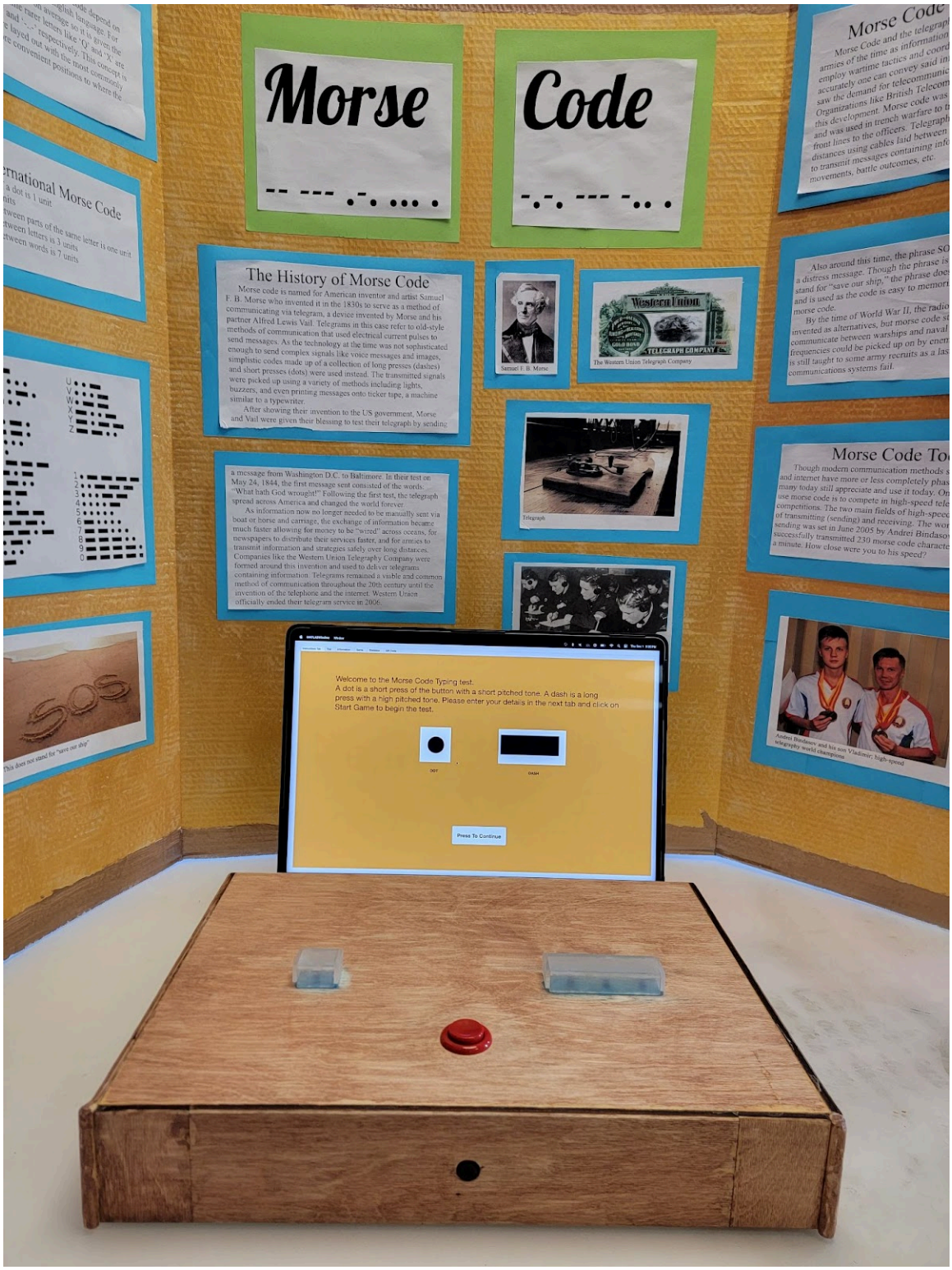
Initial iterations of the console without the wood paint finish or acrylic cover

Exhibit setup without the laptop app component and painted around the area around the LEDs blue

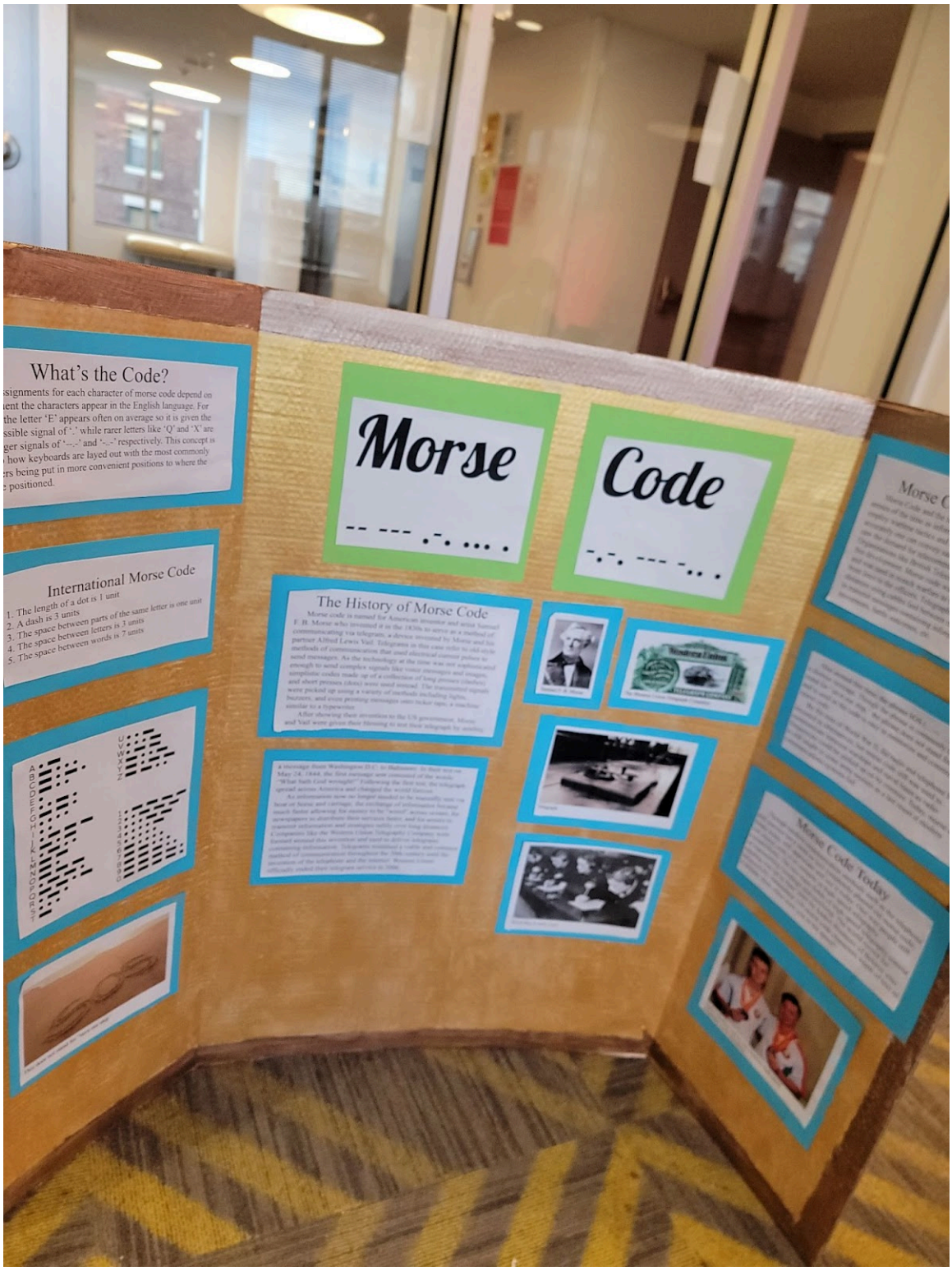
FINAL DESIGN



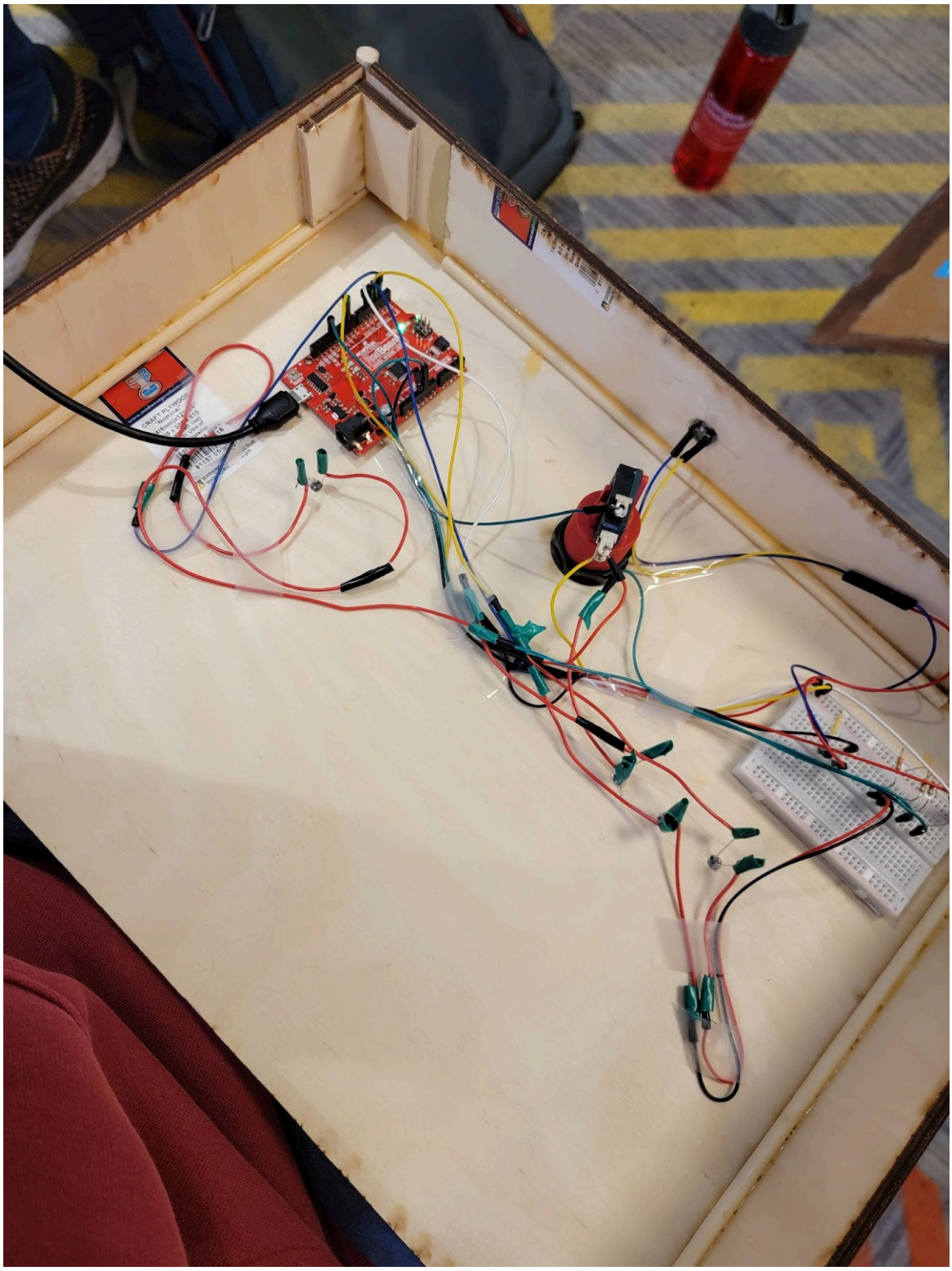
Close up of the main functional component of the exhibit with the console and the MATLAB app



A zoomed out of the main functional component of the exhibit juxtaposed to the passive element of the exhibit, the poster.



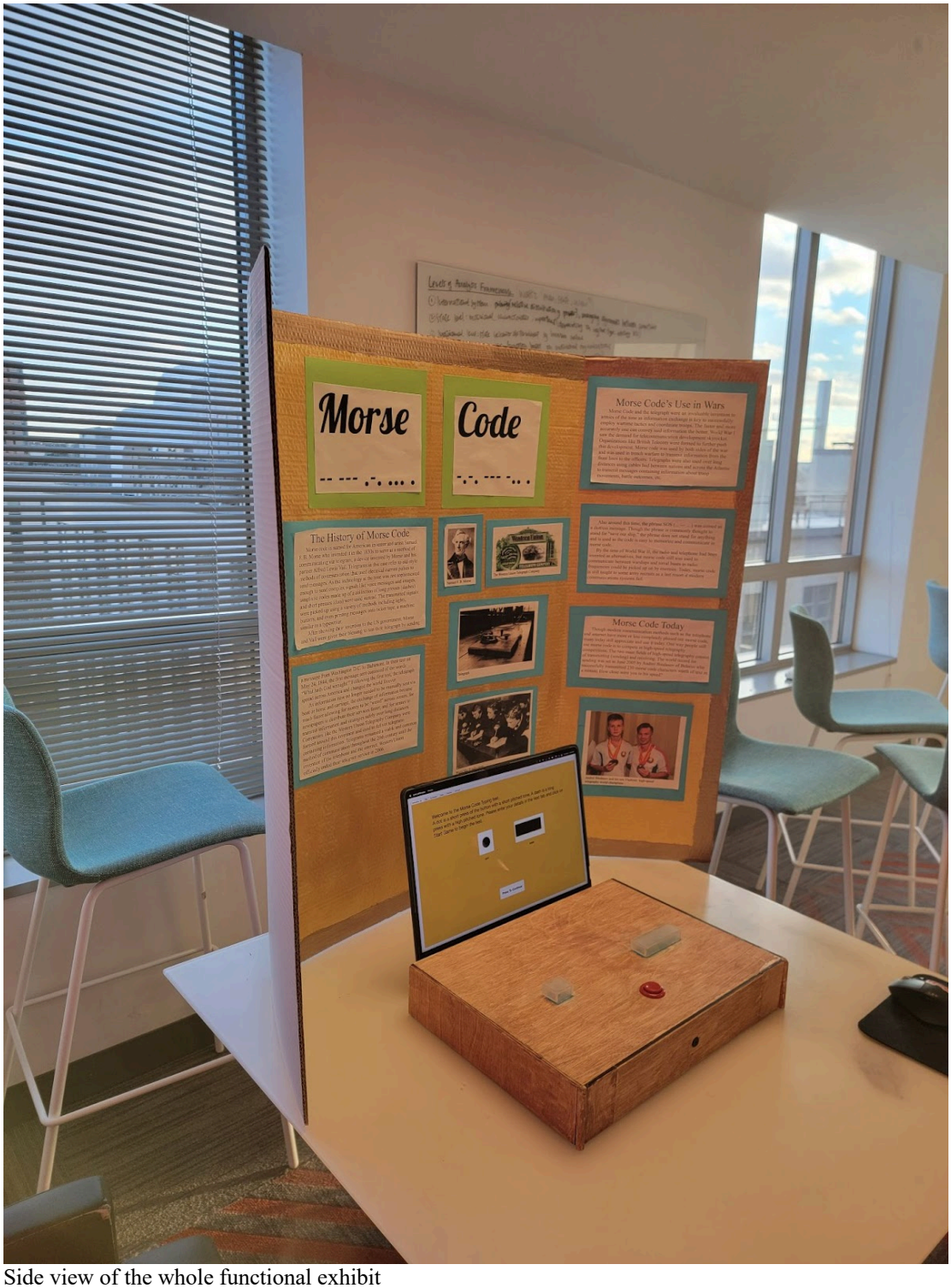
Final form of the poster



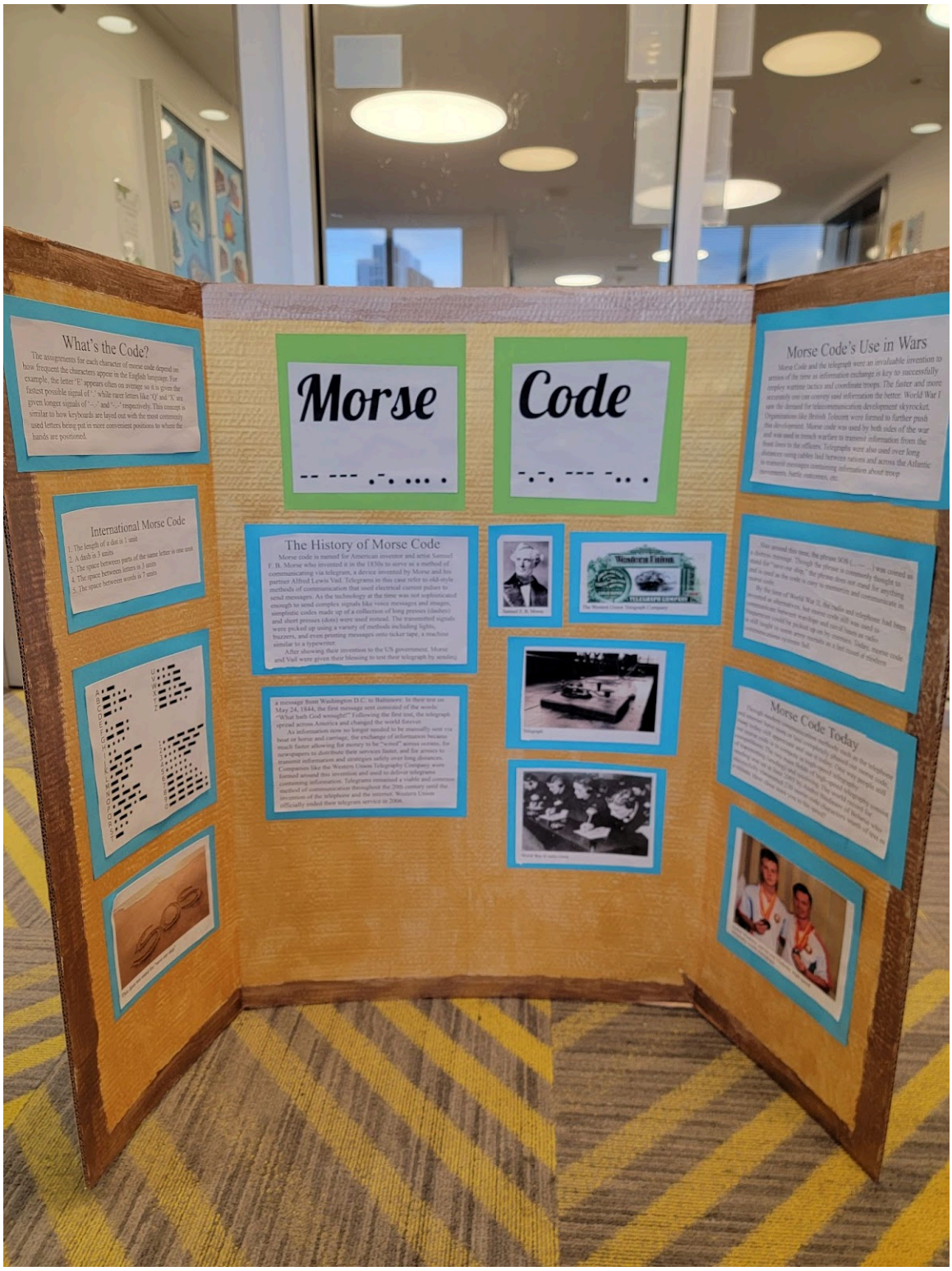
Tapped down and soldered version of the electronics underneath the console


The final exhibit in its transport configuration

D-1

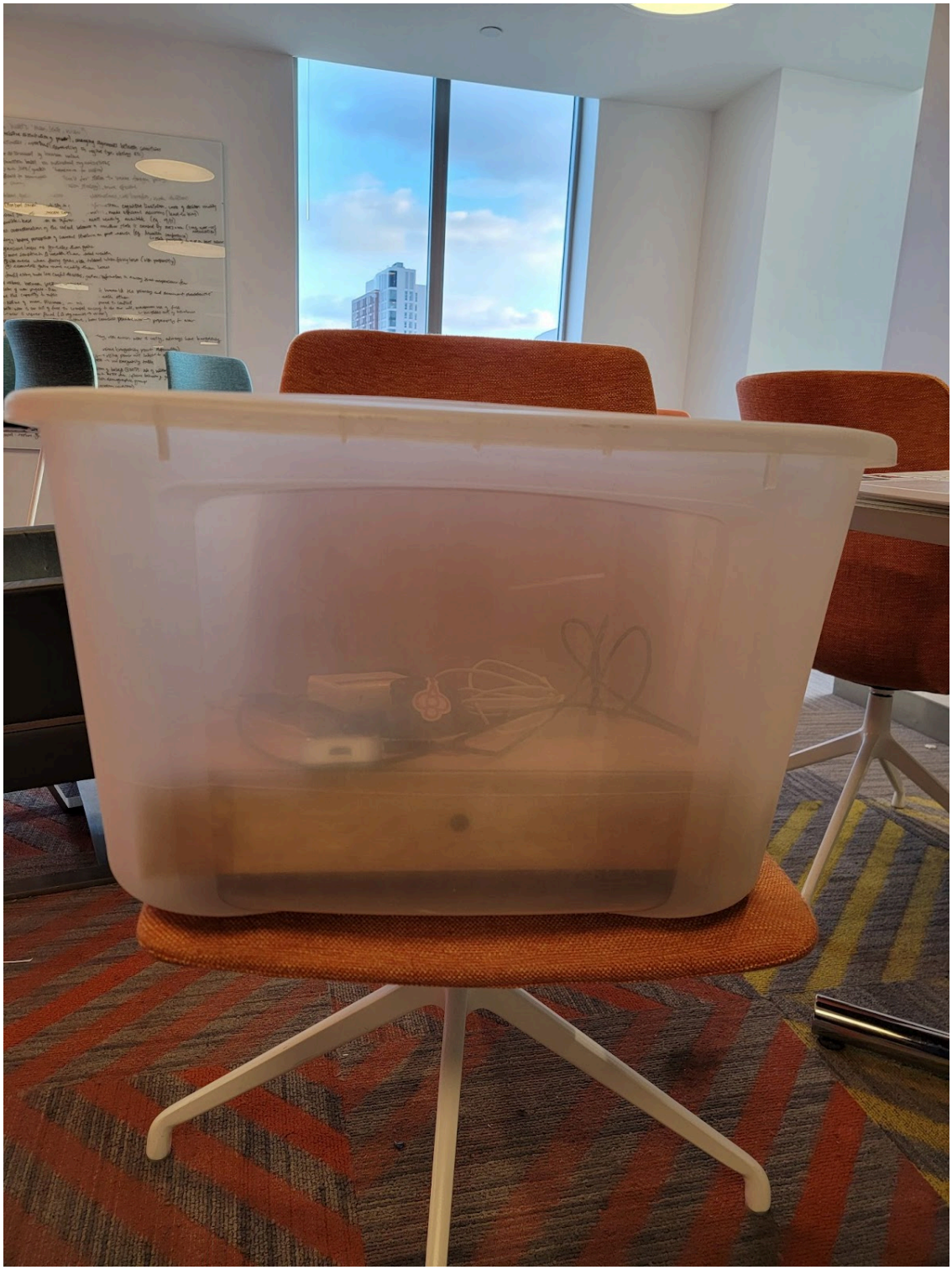


Side view of the whole functional exhibit



The passive educational component of the exhibit

E-1

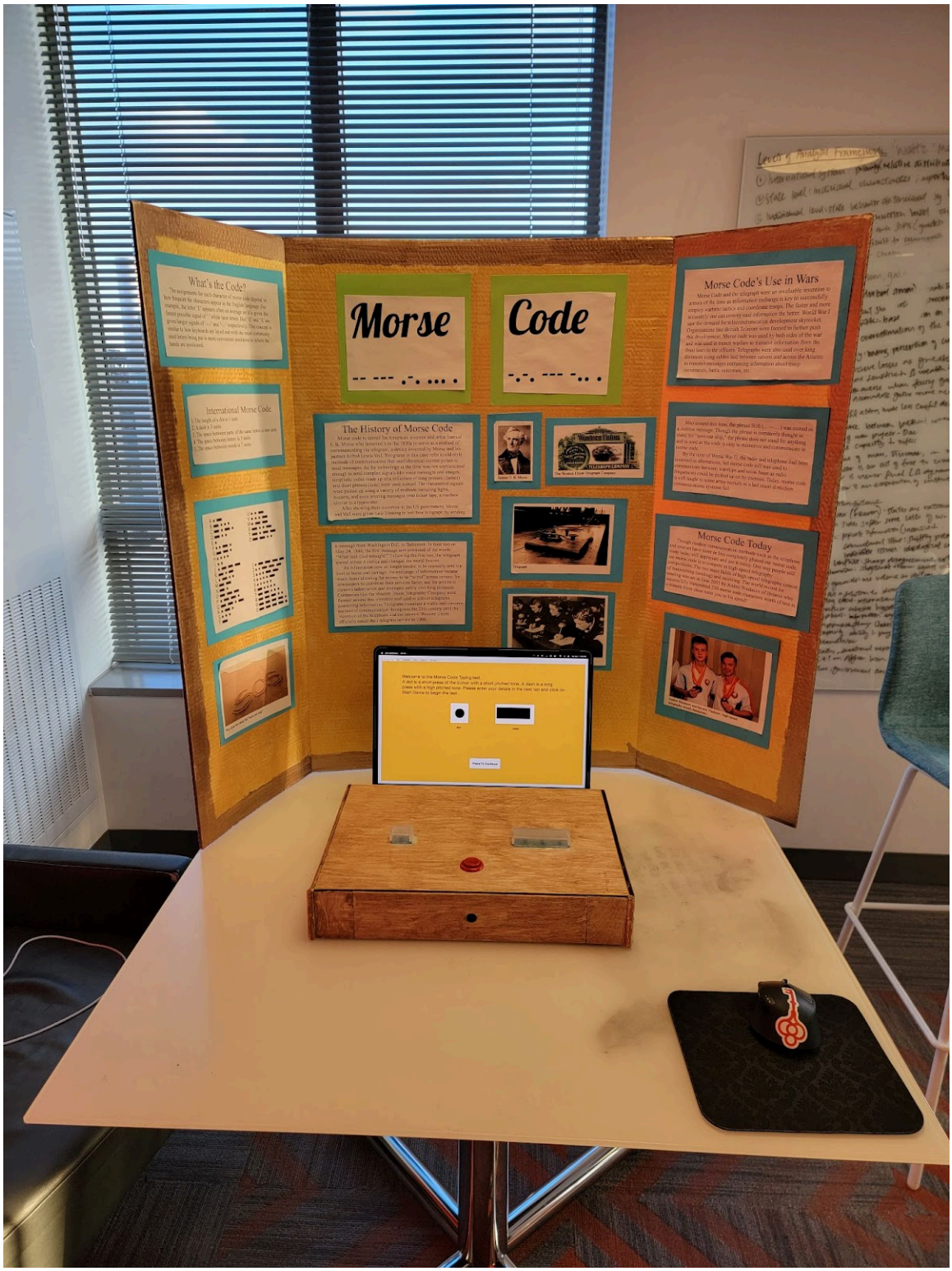


Transport configuration of the just the console and the need peripherals for the exhibit in the given bin

E-2

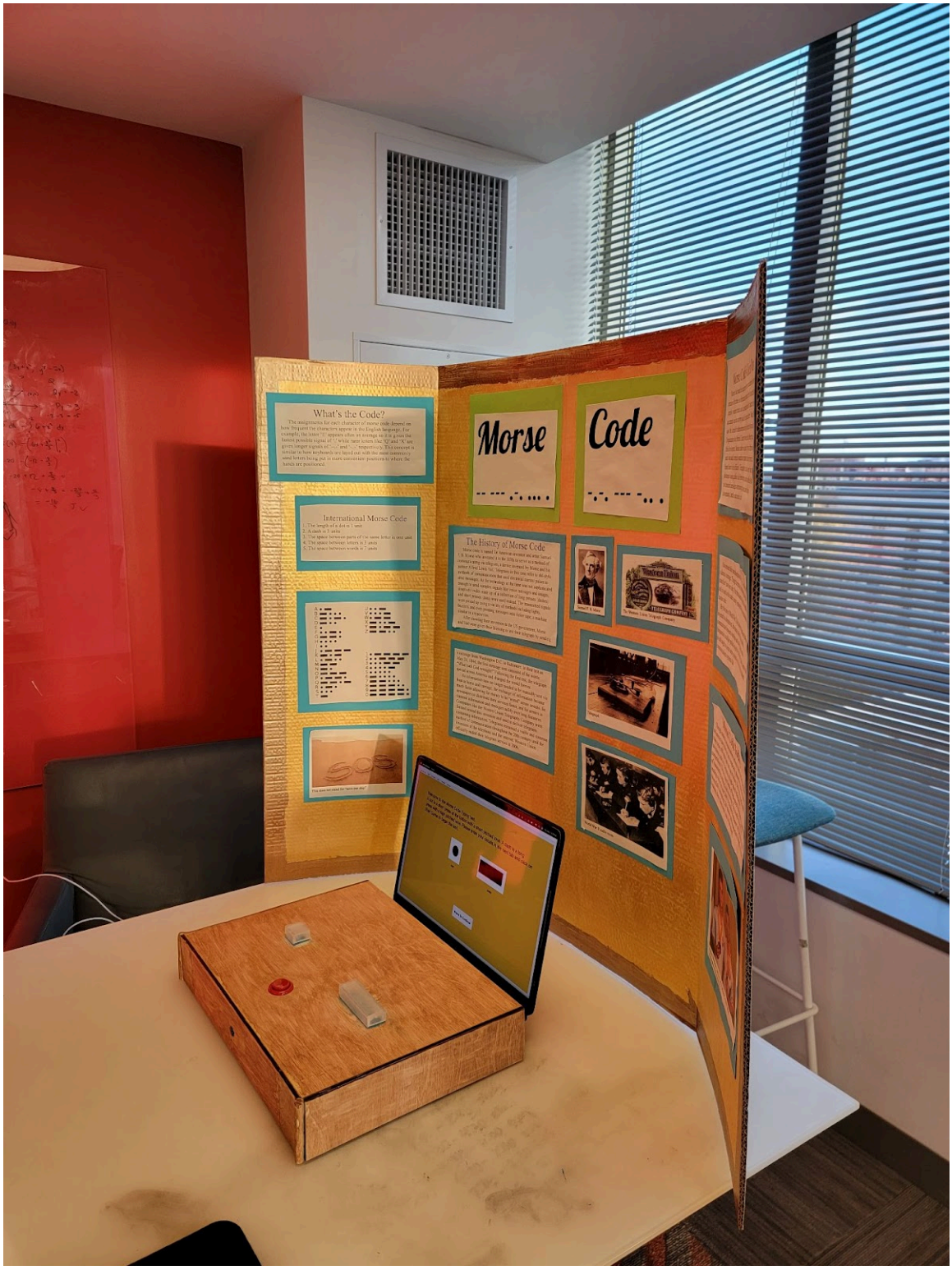
Top view of the transport configuration of the console in the provided bin

D-2



Front view of the final exhibit

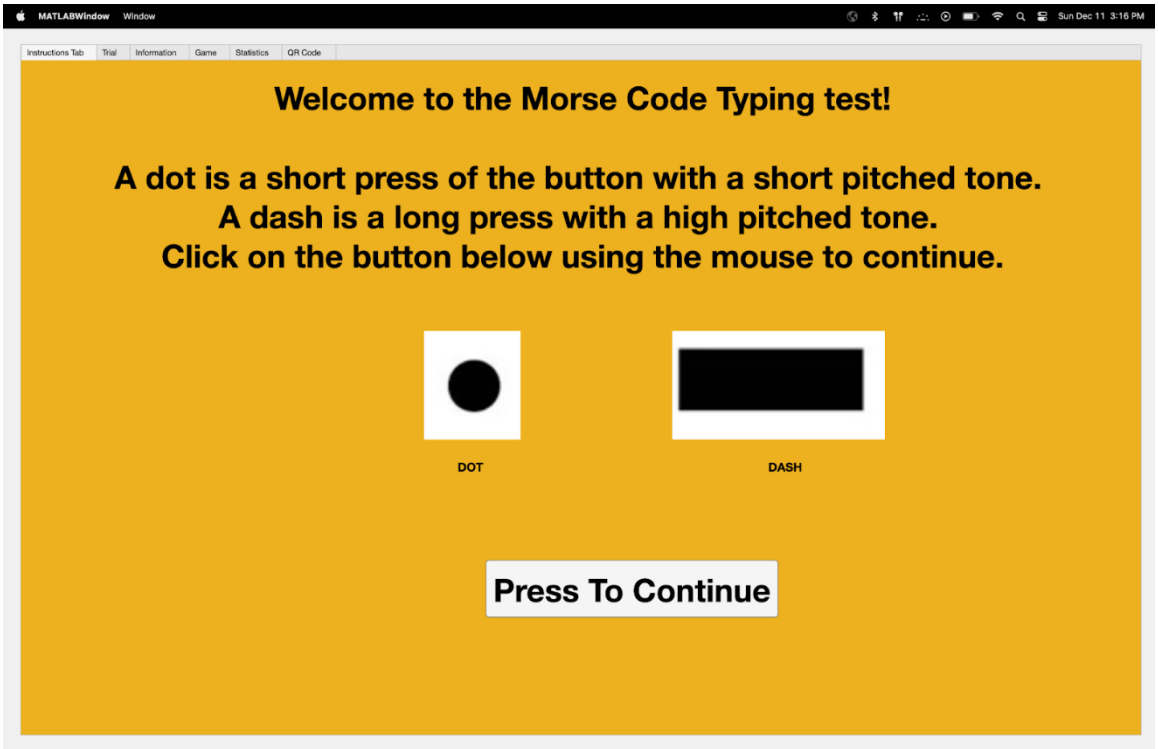
D-3



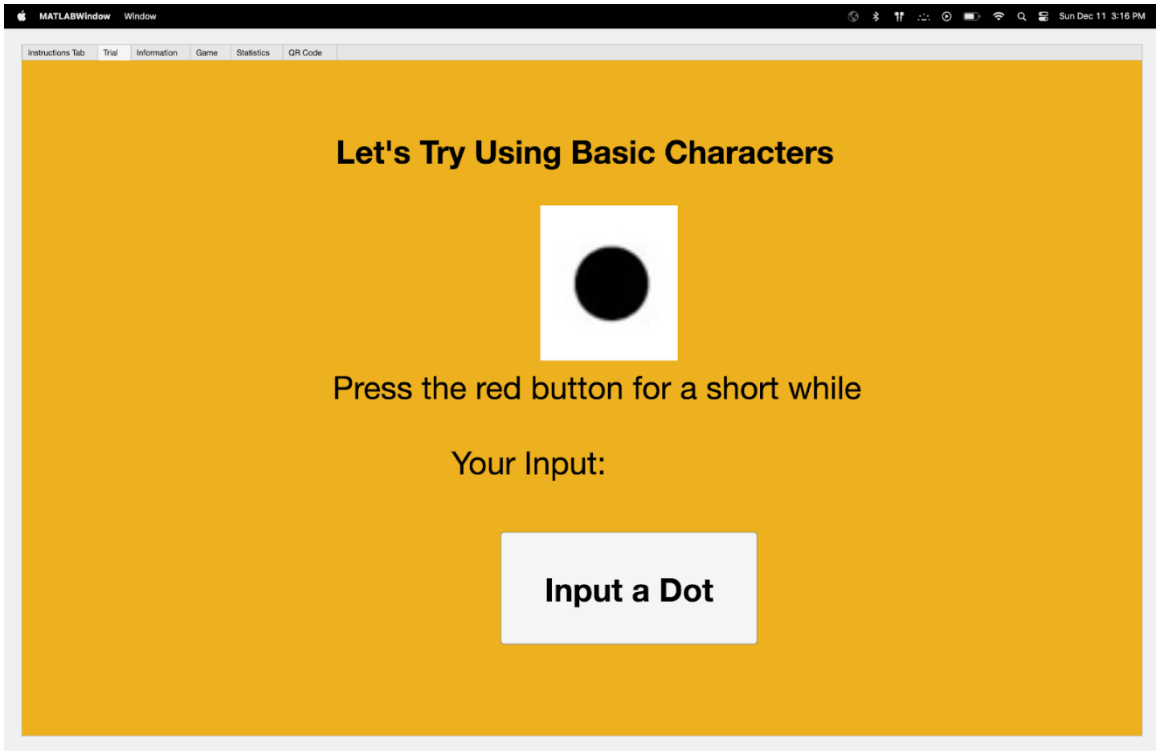
Side view of the final exhibit

D-4

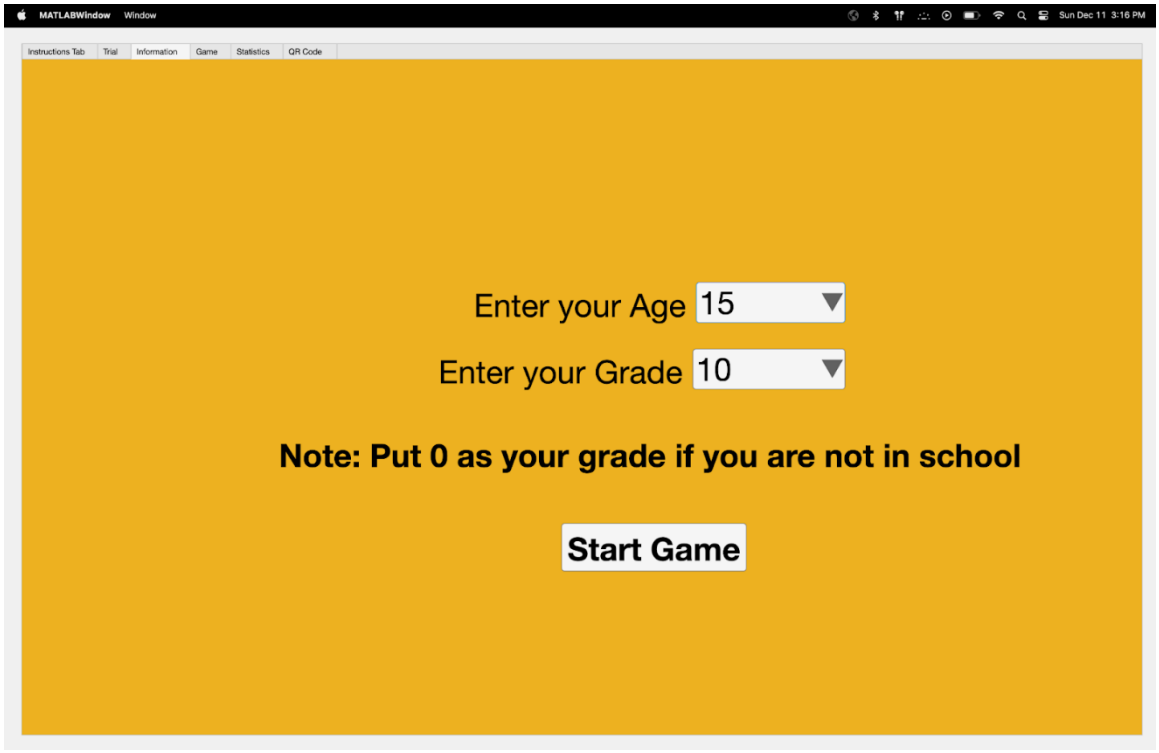
The exhibit being used by Zachary Usher in its final form



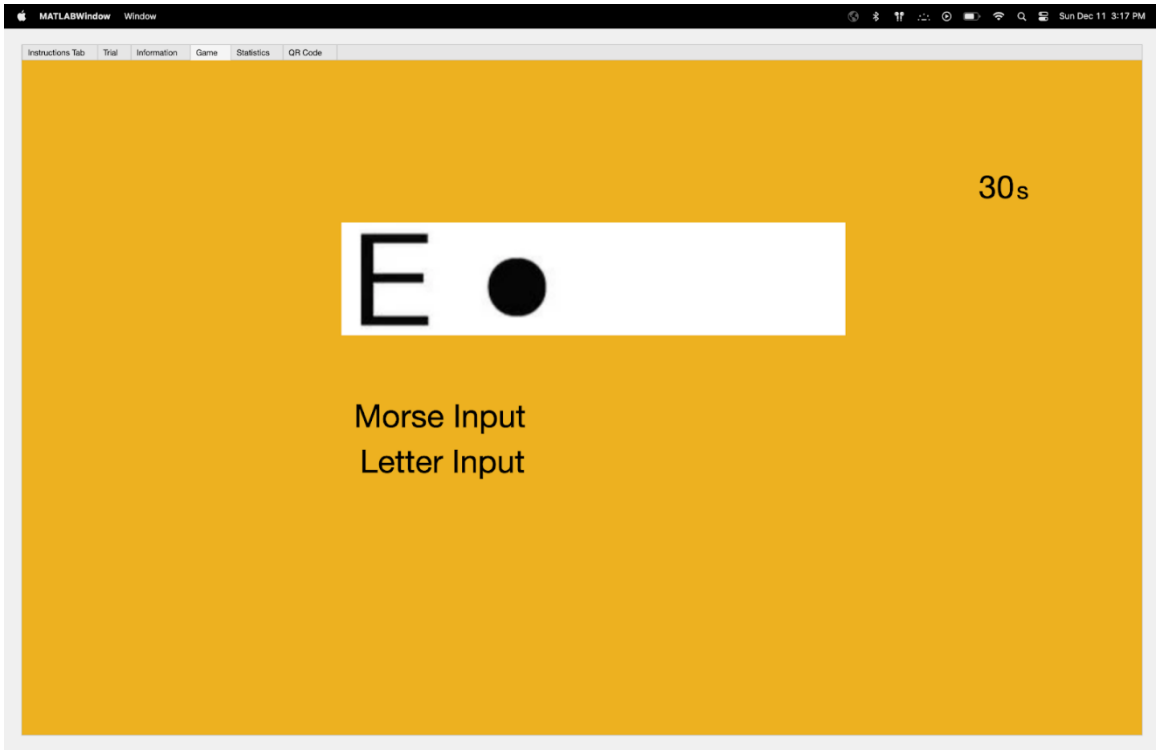
Information tab



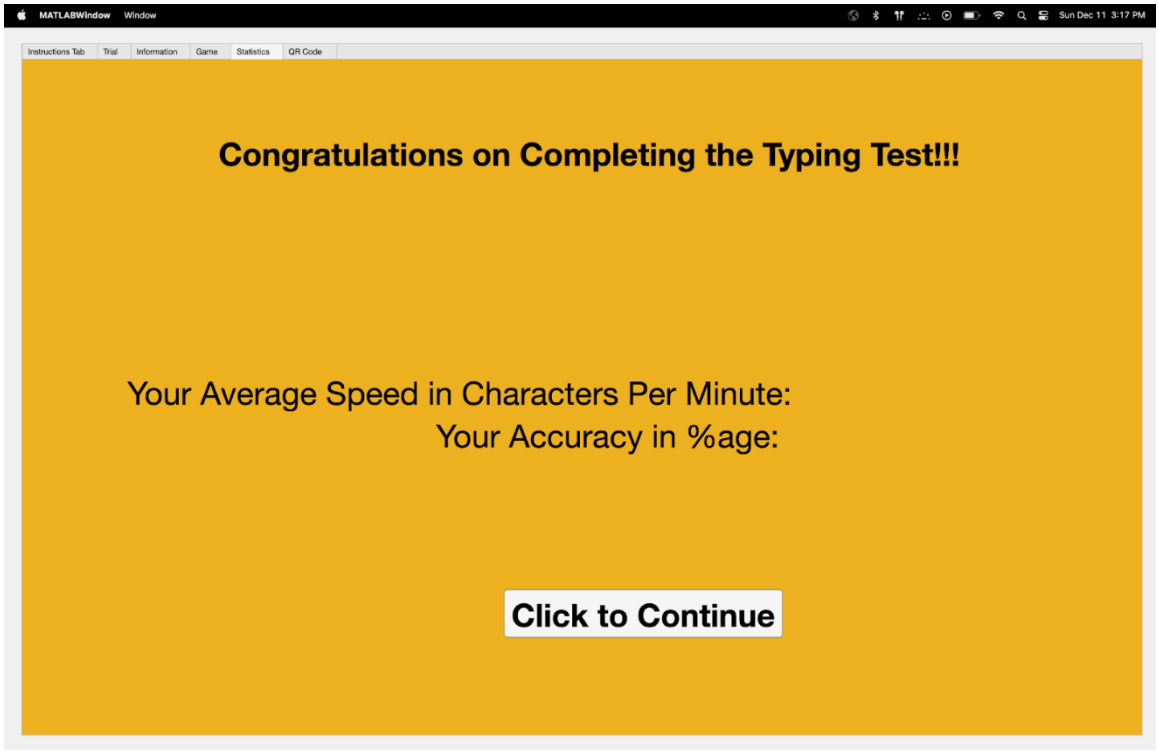
The “tutorial” tab



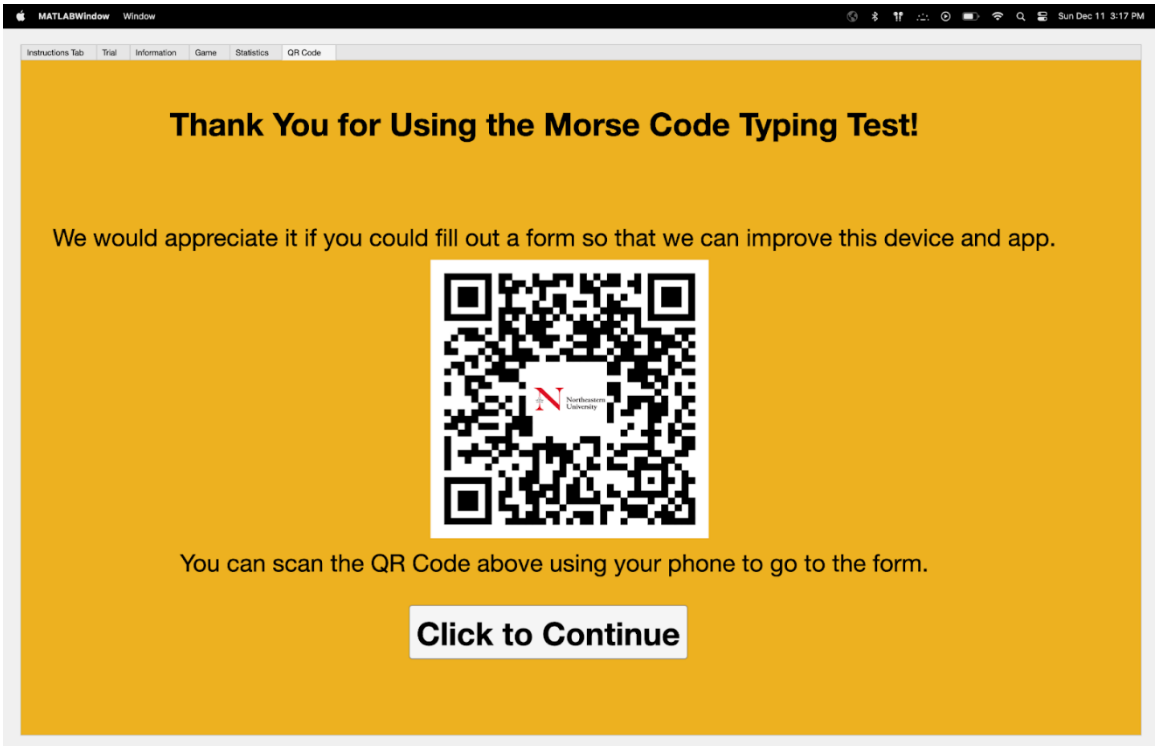
Data collection tab for user age and grade.



This is right at the where the game begins and has the input they needed to put and how to input it.

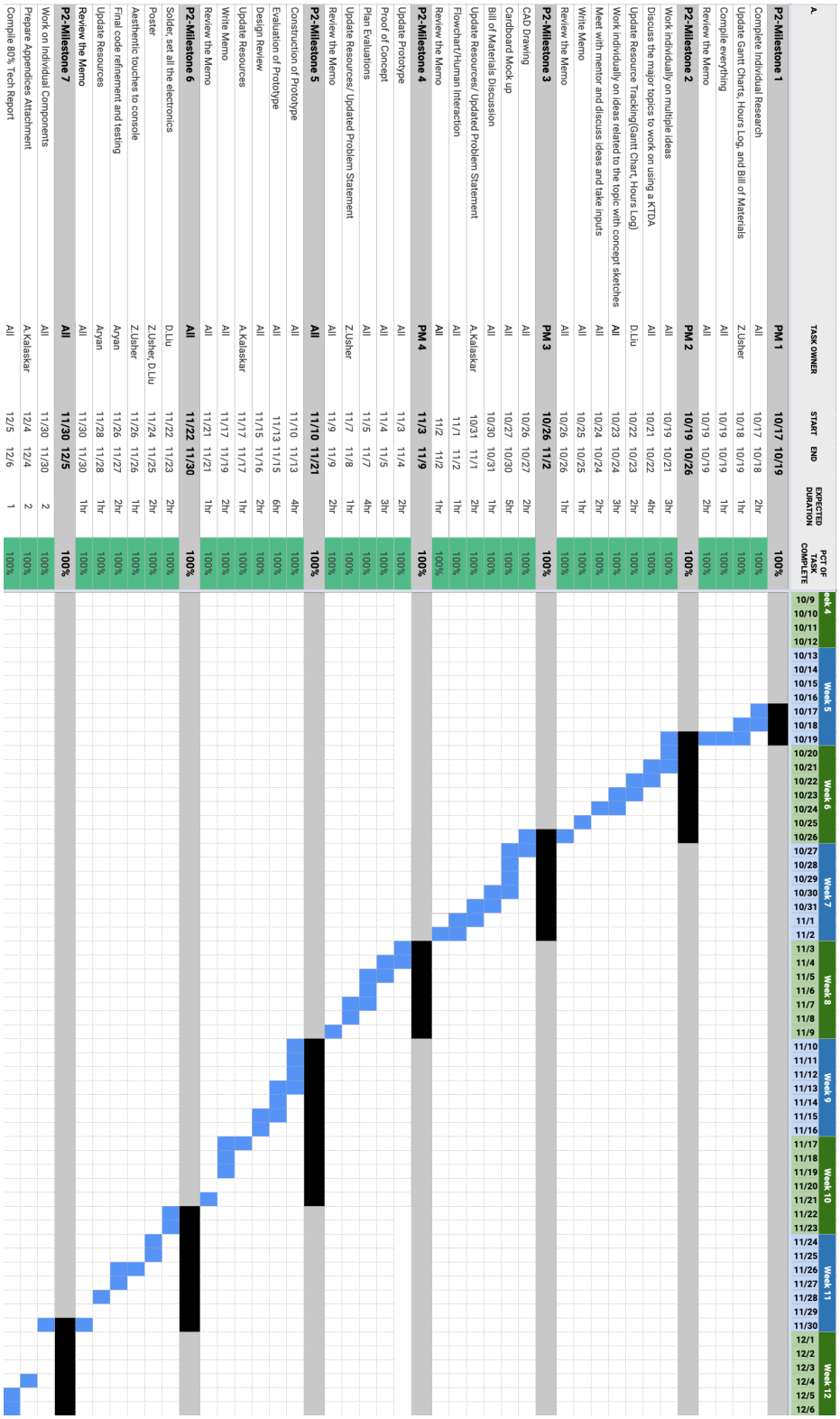


This tab will compile how well the user did and display their typing speed and their accuracy



This is the tab that will display a QR code that will be linked to a form that will ask questions about how we can improve our design.

APPENDIX H – FINAL GANNT CHART



A.	TASK OWNER	START	END	EXPECTED DURATION	PCT OF TASK COMPLETE
P2-Milestone 1	**PM 1**	**10/17**	**10/19**		**100%**
Complete Individual Research	All	10/17	10/18	2hr	100%
Update Gantt Charts, Hours Log, and Bill of Materials	Z.Usher	10/18	10/19	1hr	100%
Compile everything	All	10/19	10/19	1hr	100%
Review the Memo	All	10/19	10/19	2hr	100%
P2-Milestone 2	**PM 2**	**10/19**	**10/26**		**100%**
Work individually on multiple ideas	All	10/19	10/21	3hr	100%
Discuss the major topics to work on using a KTDA	All	10/21	10/22	4hr	100%
Update Resource Tracking(Gantt Chart, Hours Log)	D.Liu	10/22	10/23	2hr	100%
Work individually on ideas related to the topic with concept sketches	All	10/23	10/24	3hr	100%
Meet with mentor and discuss ideas and take inputs	All	10/24	10/24	2hr	100%
Write Memo	All	10/25	10/25	1hr	100%
Review the Memo	All	10/26	10/26	1hr	100%
P2-Milestone 3	**PM 3**	**10/26**	**11/2**		**100%**
CAD Drawing	All	10/26	10/27	2hr	100%
Cardboard Mock up	All	10/27	10/30	5hr	100%
Bill of Materials Discussion	All	10/30	10/31	1hr	100%
Update Resources/ Updated Problem Statement	A.Kalaskar	10/31	11/1	2hr	100%
Flowchart/Human Interaction	All	11/1	11/2	1hr	100%
Review the Memo	All	11/2	11/2	1hr	100%
P2-Milestone 4	**PM 4**	**11/3**	**11/9**		**100%**
Update Prototype	All	11/3	11/4	2hr	100%
Proof of Concept	All	11/4	11/5	3hr	100%
Plan Evaluations	All	11/5	11/7	4hr	100%
Update Resources/ Updated Problem Statement	Z.Usher	11/7	11/8	1hr	100%
Review the Memo	All	11/9	11/9	2hr	100%
P2-Milestone 5	**All**	**11/10**	**11/21**		**100%**
Construction of Prototype	All	11/10	11/13	4hr	100%
Evaluation of Prototype	All	11/13	11/15	6hr	100%
Design Review	All	11/15	11/16	2hr	100%
Update Resources	A.Kalaskar	11/17	11/17	1hr	100%
Write Memo	All	11/17	11/19	2hr	100%
Review the Memo	All	11/21	11/21	1hr	100%
P2-Milestone 6	**All**	**11/22**	**11/30**		**100%**
Solder, set all the electronics	D.Liu	11/22	11/23	2hr	100%
Poster	Z.Usher,D.Liu	11/24	11/25	2hr	100%
Aesthentic touches to console	Z.Usher	11/26	11/26	1hr	100%
Final code refinement and testing	Aryan	11/26	11/27	2hr	100%
Update Resources	Aryan	11/28	11/28	1hr	100%
Review the Memo	All	11/30	11/30	1hr	100%
P2-Milestone 7	**All**	**11/30**	**12/5**		**100%**
Work on Individual Components	All	11/30	11/30	2	100%
Prepare Appendices Attachment	A.Kalaskar	12/4	12/4	2	100%
Compile 80% Tech Report	All	12/5	12/6	1	100%

APPENDIX I – FINAL BUDGET

Item	Unit Value	Units	Qty	Value	Cost	Source	MFR PN/Link	Notes
Arduino UNO	$11.86	6	2	12	$0.00	amazon.com	EUDAX, Link	Taken from the SparkFun Inventor Kit
Wood/MDF Board	$19.00	1	1	$19.00	$19.00	craftcloset.com	Unknown, Link	May be sourced from FYELIC if available.
Glue	$1.69	1	1	0	$0.00	Target	Elmer's, Link	May be sourced from FYELIC if available.
Arcade Button	$8.79	1	1	$8.79	$0.00	amazon.com	Unknown, Link	Sourced from Professor O'Connell.
Laptop	$2000.00	1	1	$2000.00	$0.00	Aryan	Apple	Sourced from Aryan
Breadboard and Jumper Wires	$15.99	1	1	$15.99	$0.00	amazon.com	Sunxeke, Link	Taken from the SparkFun Inventor Kit
Piezo Buzzer	$7.28	10	1	$0.73	$0.00	amazon.com	Gikfun, Link	Taken from the SparkFun Inventor Kit
Wood Finish	$10.00	1	1	$10	$10	Paint Store	Generic	N-A
Poster Board	$10.00	1	1	$10.00	$10	Art Store	Generic	N-A
Paint	$30.00	1	1	$30.00	$30	Paint Store	Generic	N-A
LED Lights	$12.99	450	30	$0.87	$0	amazon.com	DiCUNO, Link	Taken from the SparkFun Inventor Kit
Wireless Bluetooth Mouse	$34.99	1	1	$35	$0	amazon.com	Logitech, Link	Sourced from Aryan
Acrylic Sheet	$9.99	1	1	$10	$0	amazon.com	KAITELA, Link	Sourced from FYELIC scrap Acrylic
			Totals	**$2152.35**	**$69.00**			

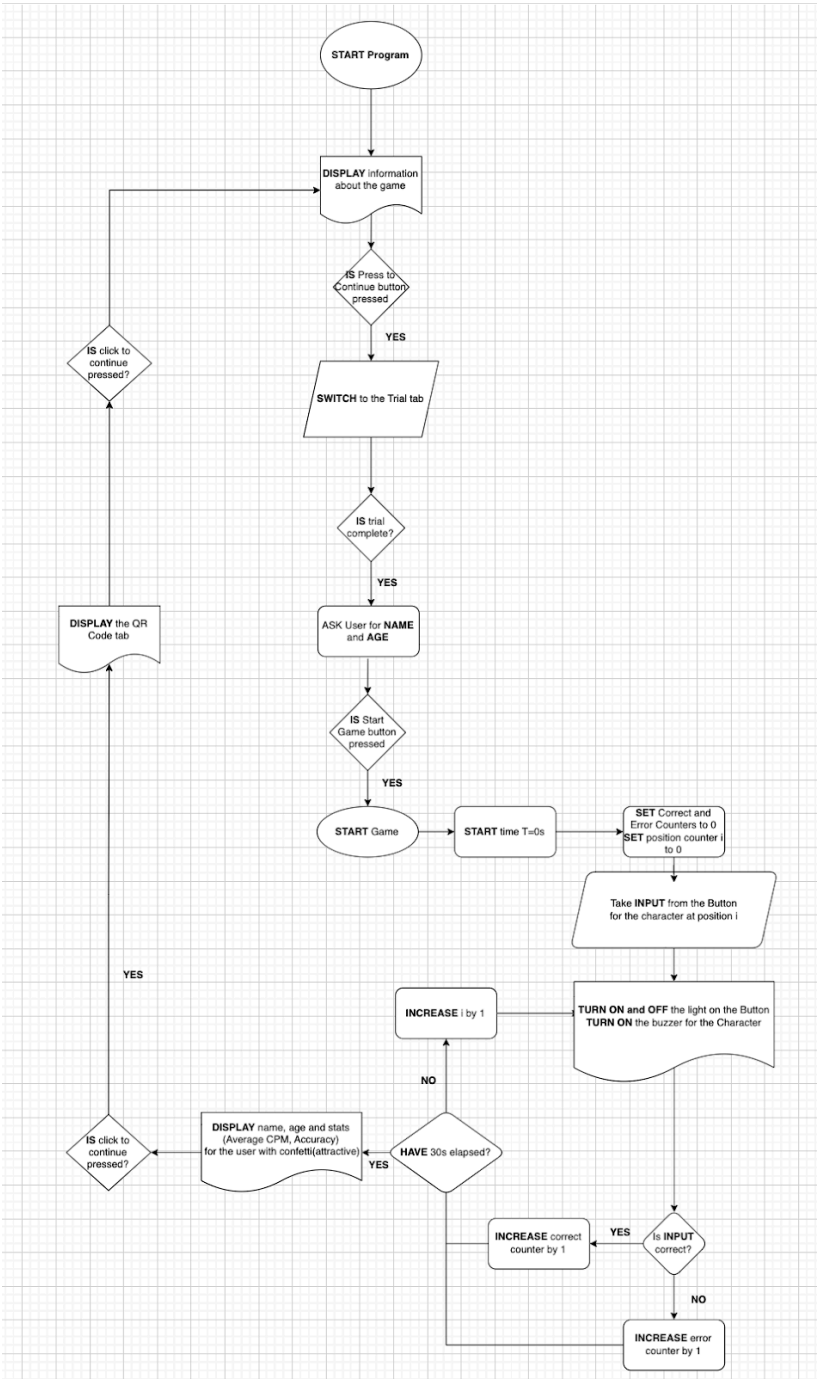
APPENDIX J – PROJECT HOURS LOG

	Aryan	Danny	Zachary	Total Work Hours
P2-Milestone 1			PM	
Complete Individual Research	2	2	2	6
Update Resource Tracking Sheets	0	0	1	1
Compile Everything	1	1	1	3
Review the Memo	2	2	2	6
Totals	5	5	6	16
P2-Milestone 2		PM		
Work individually on multiple ideas	3	3	3	9
Discuss the major topics to work on using a KTDA	4	4	4	12
Update Resource Tracking(Gantt Chart, Hours Log)	0	2	0	2
Work individually on ideas related to the topic with concept sketches	3	3	3	9
Meet with mentor and discuss ideas and take inputs	2	2	2	6
Write Memo	1	1	1	3
Review the Memo	1	1	1	3
Totals	14	16	14	44
P2-Milestone 3	PM			
CAD Drawing	2	2	2	6
Cardboard Mock up	2	2	2	6
Bill of Materials Discussion	1	1	1	3
Update Resources/ Updated Problem Statement	1	0	0	1
Flowchart/Human Interaction	1	1	1	3
Review the Memo	1	1	1	3
Totals	8	7	7	22
P2-Milestone 4			PM	
Update Prototype	2	2	2	6

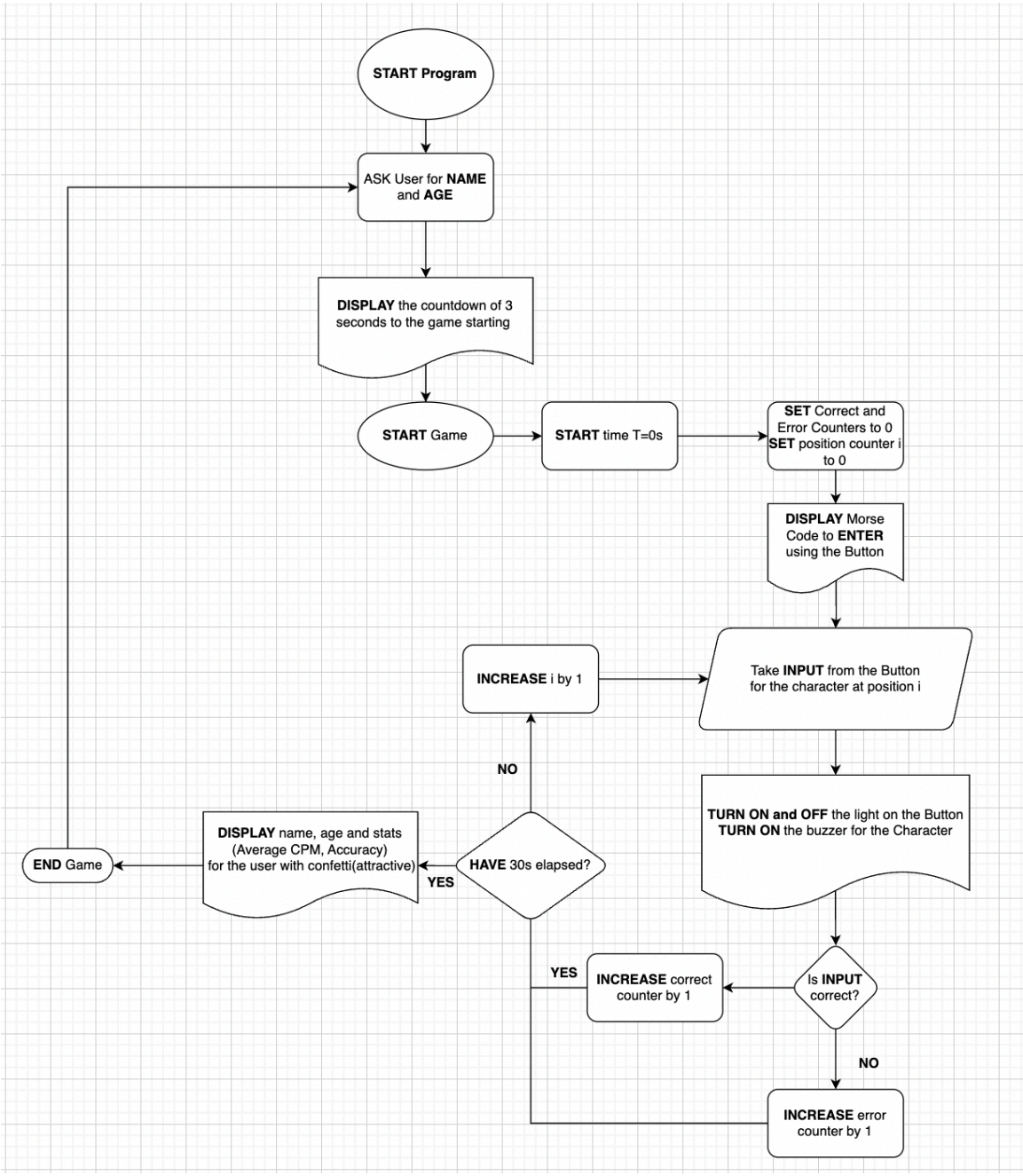
Proof of Concept	3	3	3	9
Plan Evaluations	4	4	4	12
Update Resources/ Updated Problem Statement	0	0	1	1
Review the Memo	2	2	2	6
Totals	11	11	12	34
P2-Milestone 5				
Construction of Prototype	4	4	4	12
Evaluation of Prototype	6	6	6	18
Design Review	2	2	2	6
Update Resources	1	0	0	1
Write Memo	2	2	2	6
Review the Memo	1	1	1	3
Totals	16	15	15	46
P2-Milestone 6				
Final Finishes	2	2	2	6
Poster Board Prep	0	1	1	2
Shoot the Videos	1	1	0	2
Write Memo	1	1	1	3
Review Memo	1	1	1	3
Totals	5	6	5	16
P2-Milestone 7				
Work on Individual Components	2	2	2	6
Prepare Appendices Attachment	2	0	0	2
Compile 80% Tech Report	1	1	1	3
Totals	5	3	3	11
Total Hours Spent	**64**	**63**	**62**	**189**

APPENDIX K – FLOWCHARTS

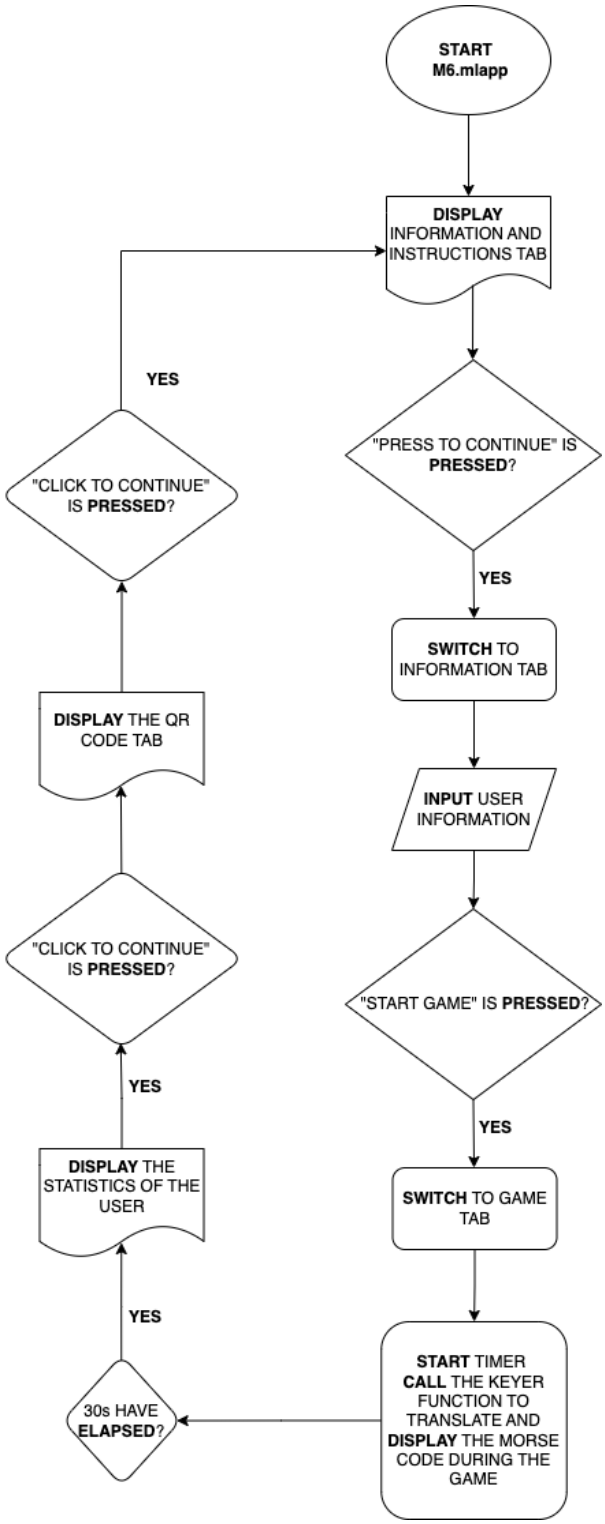
USER EXPERIENCE



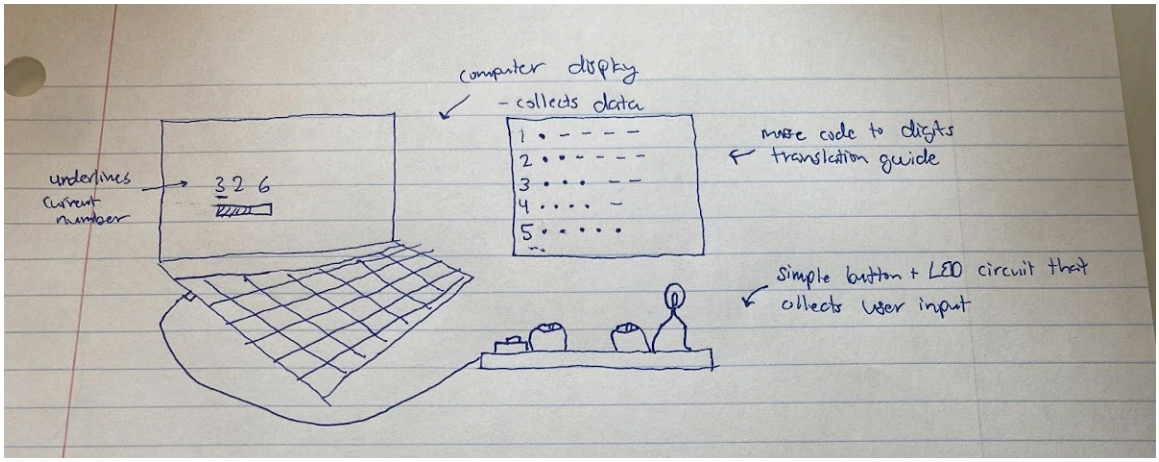
PROGRAMMING LOGIC



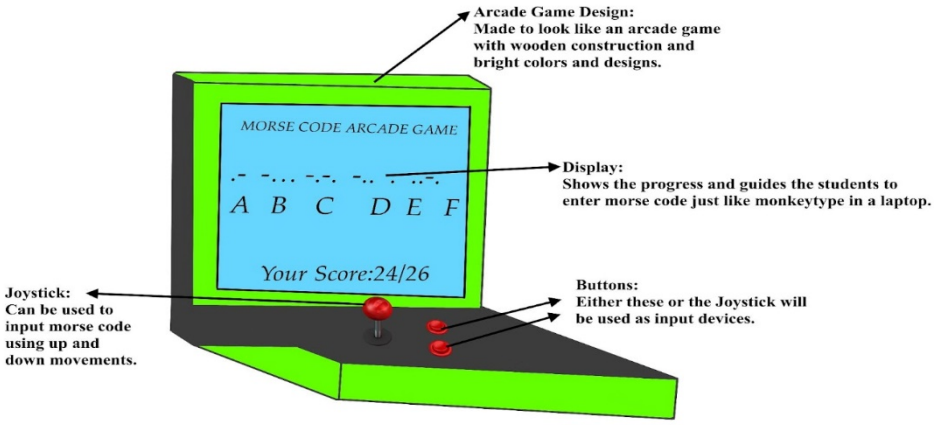
M6.MLAPP FLOWCHART



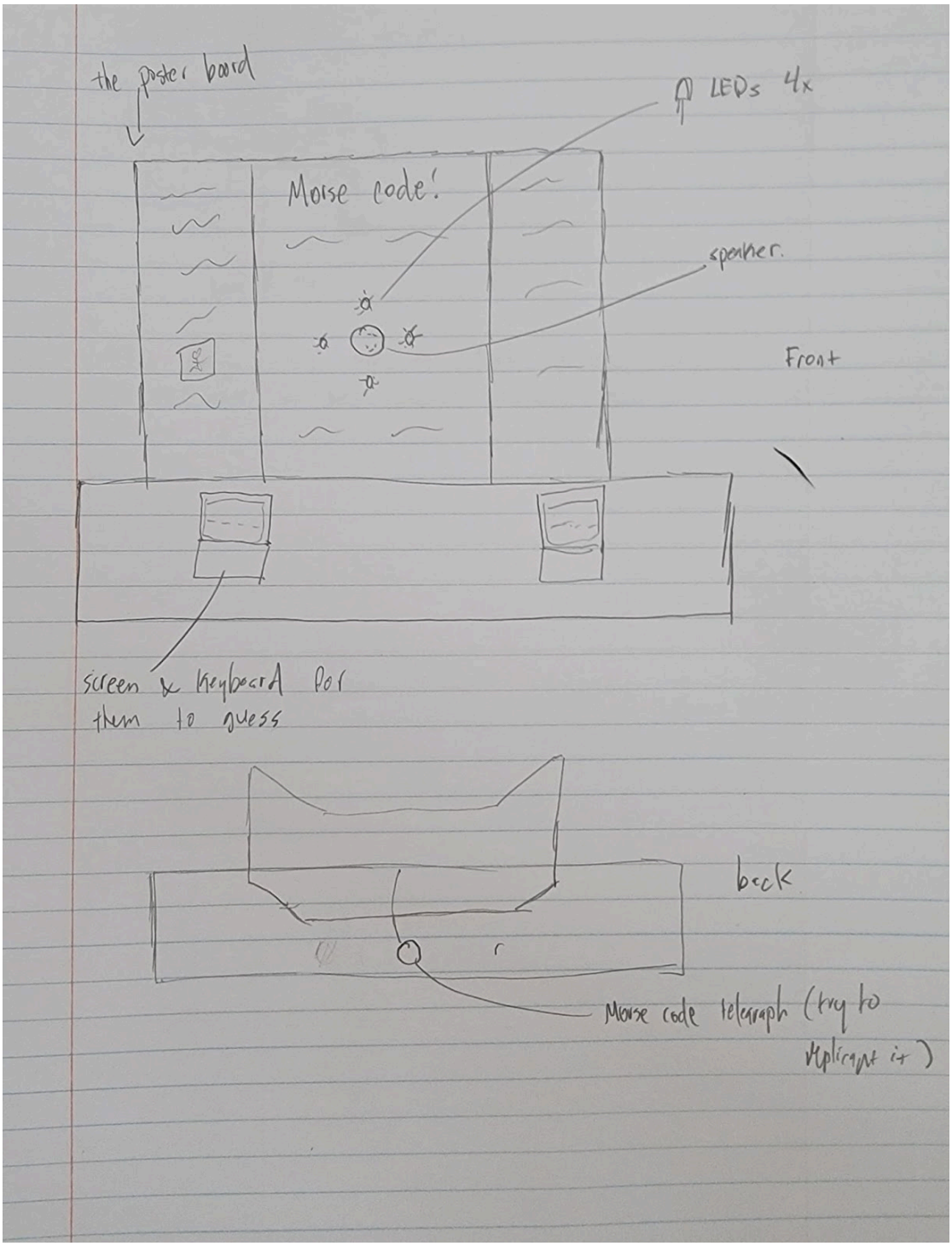
APPENDIX L – VISUAL REPRESENTATIONS



Sample drawing of possible sequence memory test idea. This would be like the human benchmark sequence memory test except with morse code as the input instead of number in the keyboard. The program would need to underline the number the user is trying to type in order to prevent confusion.



A spy gadget that I can think of is Morse Code transmitters. For this idea, I would like to make a mini arcade machine setup that has a large button to communicate morse code and there are simple letters and sentences that they can try typing out into the machine. Furthermore, we can include design changes that make use of the fact that morse code is a great language for students and people with disabilities



Having morse code being played out through audio and lights and the kids can guess what the word/letter/number (whatever we decide) was. The input can be something we thought of, or a third kid can make his own in the back.