GNG2101

Tractor Control Panel User Manual

Submitted by

Team 14

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Abstract

The Canada Agriculture and Food museum requested students from the University of Ottawa to develop a prototype for an accessible solution to one of their existing tractor exhibits. The exhibit allowed museum goers to climb into and interact with a modern-day tractor. In its current state however, many of the features of the tractor are not currently functional, including but not limited to: the vibration of the tractor engine, the lights, and the sounds. More of a concern was that the exhibit provided little opportunity for interaction for users with visual, auditory, and physical mobility impairments. Representatives from the museum wished for a solution that is much more accessible to such individuals, primarily children of ages 3-13, while maintaining or restoring some of the tractor's previous functions.

Our team planned to create a ground-based tractor control panel to eliminate the concern of impaired individuals having to climb into the tall tractor cabin. A table top control panel was developed, which included a vibrating steering wheel with a knob, a 3D compass interconnected with the steering wheel, along with various sounds triggered by buttons. The steering wheel will vibrate for a set time upon pressing of a button. The compass rotates correspondingly to the steering while through integration of a potentiometer. The is a button to trigger the sound of a tractor horn, and a lever on the board, when pulled in reverse, will cue the sound of a reversing vehicle. The aim for these components was to provide haptic, audio, and visual interactives for impaired visitors. A table top control panel will allow wheelchair bound individuals to participate in the exhibit. Vibrations and sounds from the board will provide an experience for visually impaired individuals. The vibrations and compass rotation will provide interaction cues to users with auditory impairment. The design of the board aimed to allow as many users as

possible to feel what it would be like to drive a tractor with some elements of precision agriculture in as simple of an interaction as possible.

To develop the current prototype, our team made efforts to empathize with our client to understand their problem and reach an agreement on precisely what needed to be solved. From there, we defined our mission objectives, brainstormed various solution ideas, converged on a more refined solution, developed a detailed plan of our prototypes, and began prototyping and testing. We defined many of our requirements through direct advice given by our clients, and detailed standards set by Ingenium, including dimensioning of the board, size of buttons, and more. Our final prototype was made with MDF to form the box, an Arduino to power components, simple wiring, a hollow plastic steering wheel mold, multiple vibrating motors, a potentiometer, an aluminum rod to hold the lever, three buttons, two buzzers, a DC motor, along with a 3D printed compass and symbols to adorn the board top. Vibrating motors were placed in the shell of the wheel to create the vibrating steering wheel. The wheel was attached to a potentiometer, which would communicate with an Arduino, which would power a DC motor to turn the compass. Audio components would play through a PCB 128 DB speaker; pitch of the buzzers would be adjusted to distinguish the horn and reversing siren noises. Wiring was soldered to a protoboard to finalize everything.

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List of Acronyms

Acronym	Definition
CEED	Center for Entrepreneurship and Engineering Design
CAFM	Canada Agriculture and Food Museum

1. Introduction

The CAFM aims to provide an enriching, educational experience about the history of Canadian agriculture, as well as to demonstrate advances in farming science and technology. They currently have a tractor exhibition to teach children how the machine works, although it is inaccessible in its current state to many users and lacks many of its original interactive features. The museum brings in visitors from far and wide, many of them young children, and it is most unfortunate that many of these visitors have limited opportunities to interact with the existing museum exhibits, as it takes from the visitors' experience at the museum and hampers the museum's objectives. To bring this experience to as many people as possible, our client requested we design a tractor exhibit that is both accessible to individuals of various impairments, and more interactive that the current exhibit. To meet as many of our client's needs as possible, our team created a table top interactive control panel that is designed to reproduce a simplified experience of driving a modern-day tractor. Table 1 lists prioritized needs we interpreted from our client. Many accessible tractors are designed for users with reduced mobility, however we have aspired to create a tractor exhibit for those with physical, auditory, and visual impairments. The vibrating steering wheel caters to a larger number of museum visitors, allowing them to positively interact with the panel and receive an enriching tractor experience.

Table 1: List of Prioritized Client Needs

Prioritized Needs:	Numerical Ranking System 1- 5 (five being of highest importance to achieve)
Safe Experience	5
Unsupervised Experience	5
Accurately depicts modern agriculture (precision agriculture)	4
Experience has a clear end (30sec cycles)	3
Accessible for everyone (physical disabilities, mental disabilities, age, injuries etc.)	4
Maximizes number of users at a time	2
Easy to use	5
Engaging	4
Bilingual Instructions/Labels	4

The following report details the components that make up our tractor control panel and their functionalities, along with safety guidelines and technical instructions.

2. Components and Capabilities

The interactive tabletop tractor control panel includes the following features and functions:

- A vibrating steering that activates at the push of the green “ON” button. The aim of this function was to replicate to some degree the feeling of a running tractor engine, which would vibrate the cabin.
- A horn sound triggered by the push of the yellow “horn” button. This served to resemble the sound of a tractor horn.

- A lever that can be pushed forward and pulled backwards, triggering a reversing siren sound by hitting a button when pulled back. This aimed to represent a tractor gear shaft and provide some audio cue to indicate to users that the vehicle is reversing.
- A rotating compass that rotates accordingly as the wheel is turned. The compass is powered by a DC motor, which receives instructions from an Arduino and potentiometer that is set up with the steering wheel. This was implemented to provide some degree of a precision agriculture experience, as it could resemble some form a GPS by indicating direction to users.
- Raised global symbols on the start up and horn buttons, as well as raised arrows by the lever to indicate forwards and reverse directions.

The tractor control panel was made with the following components:

- A board shell made with MDF
- A lever made with MDF
- An aluminum rod to hold the lever
- Three plastic buttons
- 3D print compass
- 3D print potentiometer cap
- 3D print “ON”, “Horn”, and up and down arrow symbols
- 3D print lever handle
- A potentiometer
- Two PCB 128 DB buzzers
- One Arduino UNO

- USB cable for Arduino
- 1 Protoboard
- Wires
- A plastic hollow shell steering wheel

The following table displays the total cost to build the prototype.

Table 2: Final Bill of Materials

Bill of Materials			
Material	**Price/Unit ($ CAD)**	**Quantity**	**Cost ($ CAD)**
Push Buttons	0.71	3	2.21
Potentiometer	0.61	1	0.61
MDF Board	4	4	4
Steering Wheel	15	1	15
Arduino Uno	17	1	17
Aluminum Rod	2.48	1	2.48
Stepper motor + ULN2003 driver	2.26	1	2.26
Wood Glue	6.77	1	6.77
Vibrating Mini Motor Disc	4	4	16
PCB Mount Mini Speaker	4	1	4
Total	$70.33 + tax (13%) =79.57		

2.1 The MDF Board

Our team created the shell of the control panel by cutting and assembling ¼ inch MDF board. Each of the pieces were attached with gorilla wood glue except for the top piece, which secures itself with cut slots. The top can be removed and reinserted with ease, in case any internal components need to be adjusted or replaced. Figure 1 and 2 display the board pieces assembled together.

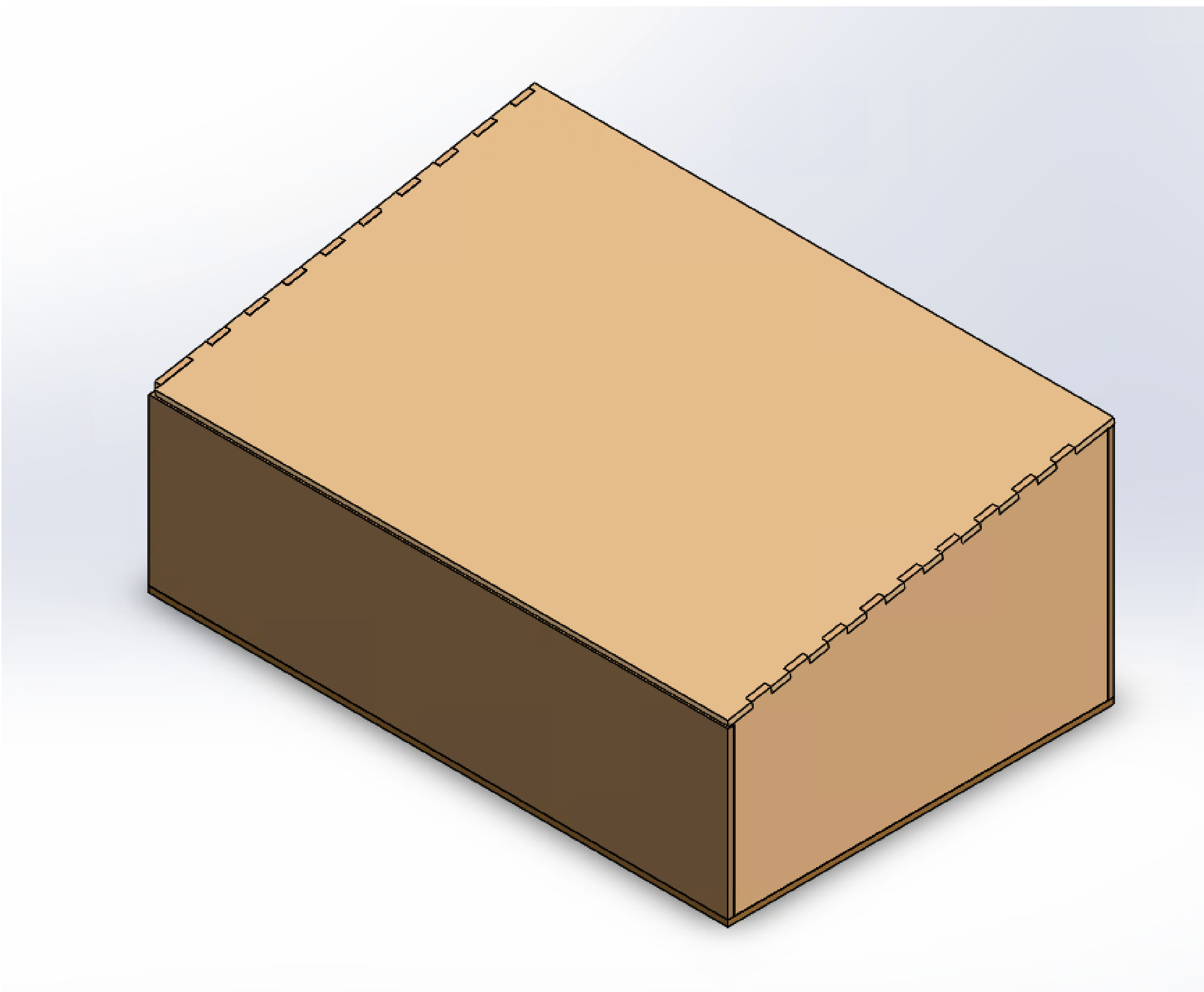

Figure 1 Front view of board assembly (SOLIDWORKS model)

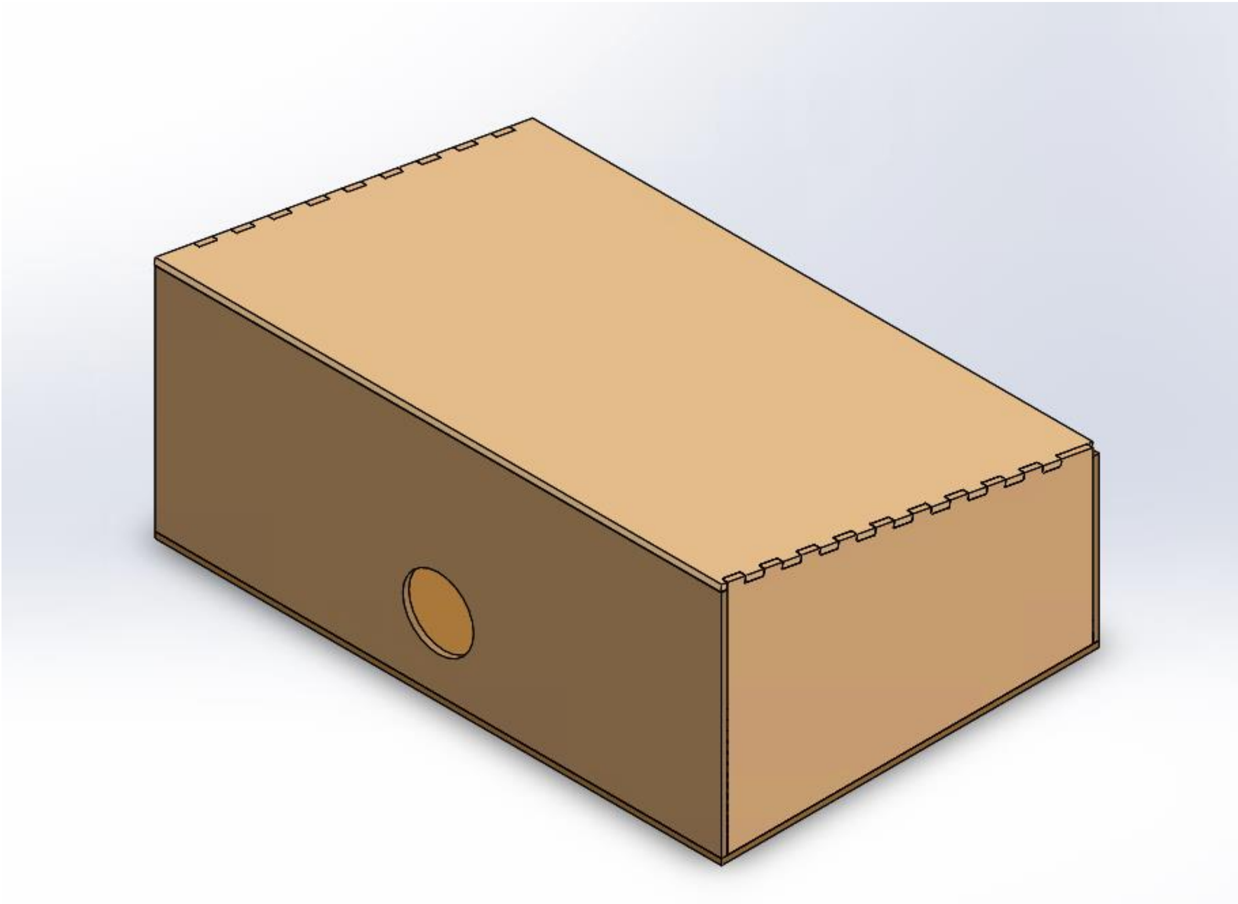

Figure 2 Rear view of board assembly (SOLIDWORKS model)

Refer to Appendix A for the necessary files for laser cutting the board pieces. It should be noted that the laser cutting settings used to cut the board were 20, 70, and 500 for speed (%), power (%), and frequency (Hz) respectively.

2.2 The Lever

Our team used left over MDF board to cut a lever, two supports for an aluminum rod, and supports to hold a button. A 1” diameter, 4” length aluminum rod was ordered and used as a shaft for the lever. Figure 3 shows the lever. Components were secured to the MDF board using gorilla wood glue. Refer to Appendix A for the laser cutting file. It should be noted that the pieces were cut from left over MDF after cutting the side pieces, and two levers were cut and glued together to double the thickness. Furthermore, it when assembling the pieces, the aluminum rod did not quite fit into the lever and rod supports. This may be due to precision error in the diameter of the aluminum rod. To ensure the fit, we filed the holes in the lever and support pieces to ensure that there was a loose fit with the lever and a tight fit with the supports.

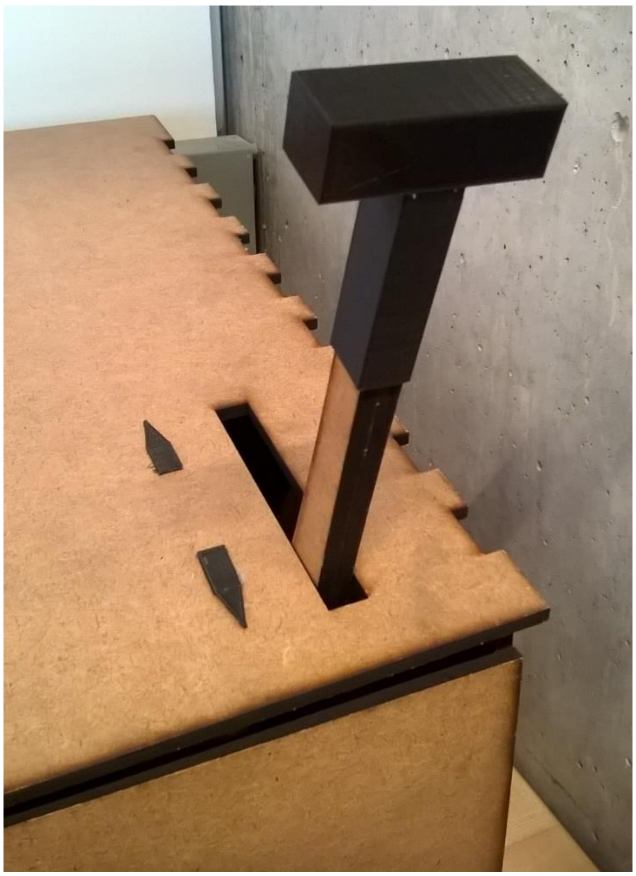

Figure 3 Lever with handle, inserted into the slot

Additionally, some left over MDF pieces were glued onto the bottom of the lever to create a hammer to hit the button, since with our placement the lever bottom didn’t quite hit the button when pulled back. Figure 4 details the approximate placement of the supports. The lever set up is located on the bottom right corner of the board base. Lastly, our team 3D printed a lever handle to attach on top of the lever, and two thin arrows to place beside it. Necessary files can be found on MakerRepo.

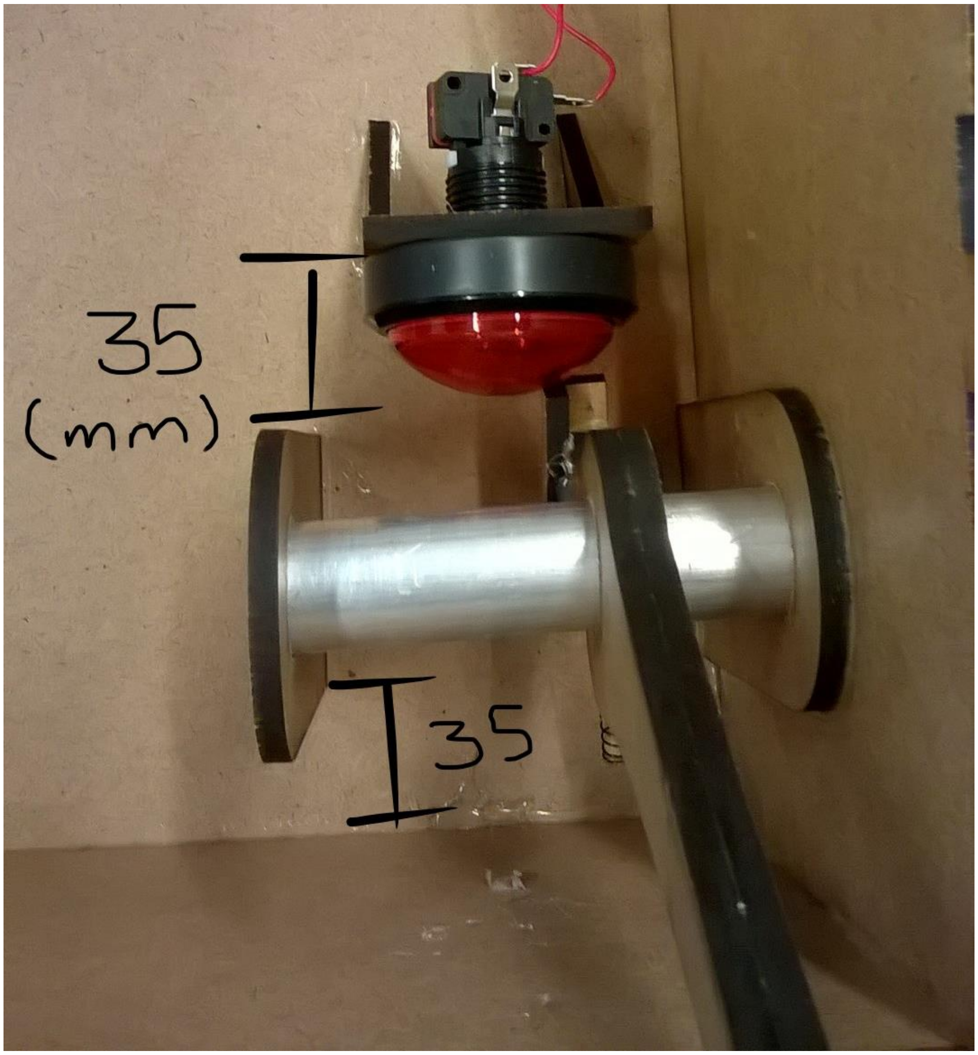

Figure 4 Placement of rod supports and button support

When the lever is pulled back, it will hit the red button and trigger the reversing siren sound for a set time.

2.3 The Wheel

- Vibration motors were placed inside the wheel, and were activated for 10 seconds when a green “start” button on the MDF board was pressed

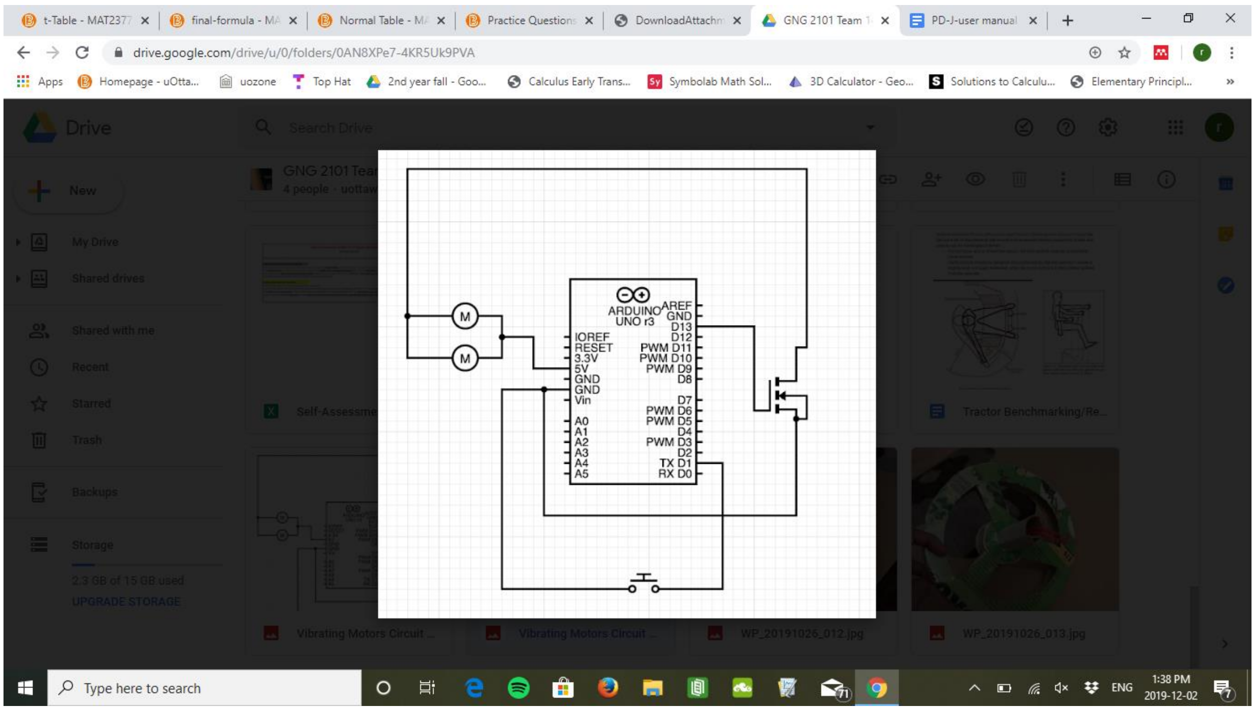

Figure 5 Vibration Motor Circuit

A speaker that emitted a honking noise when activated was also placed on the wheel to ensure optimal sound level. The speaker was activated when the yellow “horn” button on the MDF was pressed

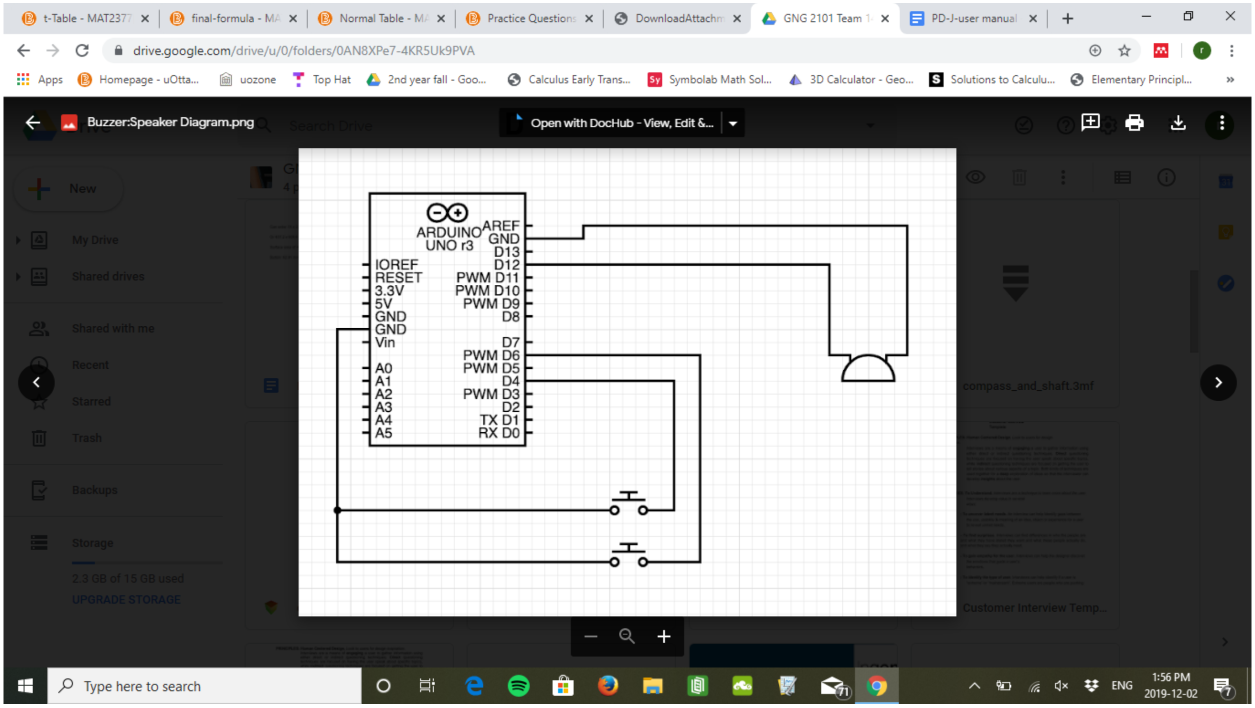

Figure 6 Buzzer Speaker Circuit

- The wheel was also attached to the potentiometer cap, which would turn the potentiometer in the same direction that the wheel was turned.
- A 3D printed "suicide knob" was also attached to the wheels so that those with dexterity issues can still move the wheel

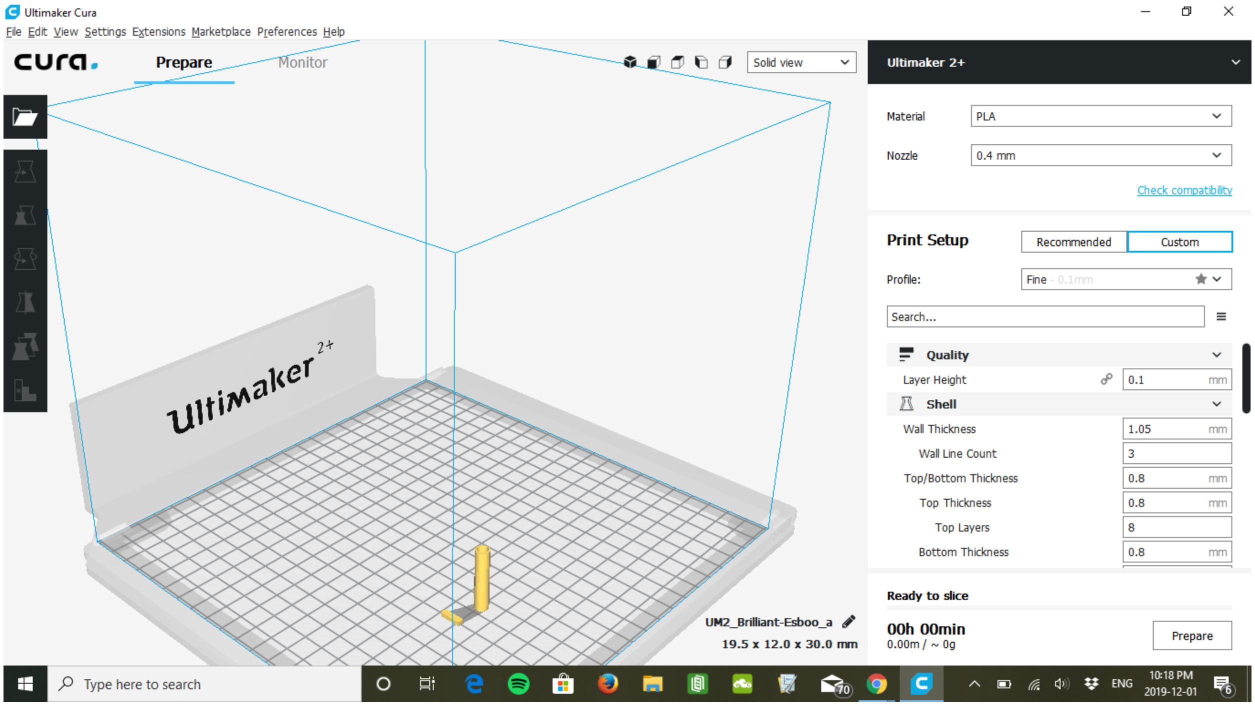

Figure 7 3D model of steering knob

2.4 The Compass

- A tactile compass was used to indicate the motion of the tractor when the wheel was turned.

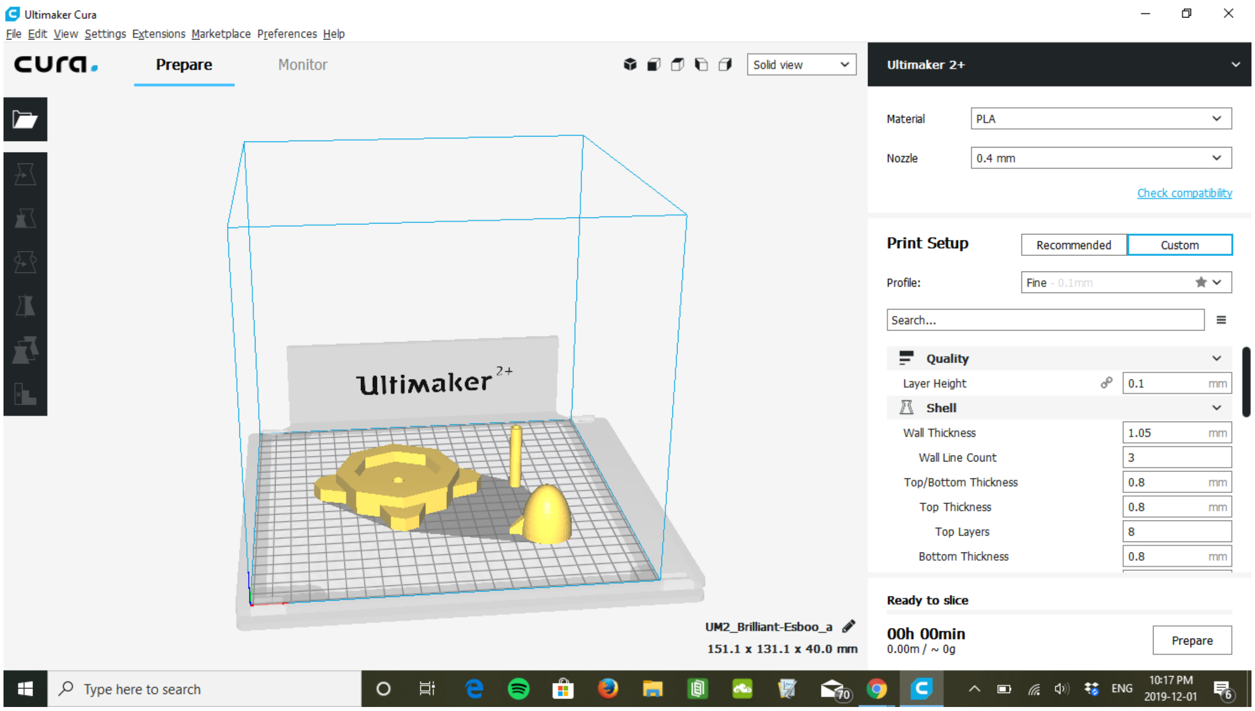

Figure 8 3D model of compass components (front view)

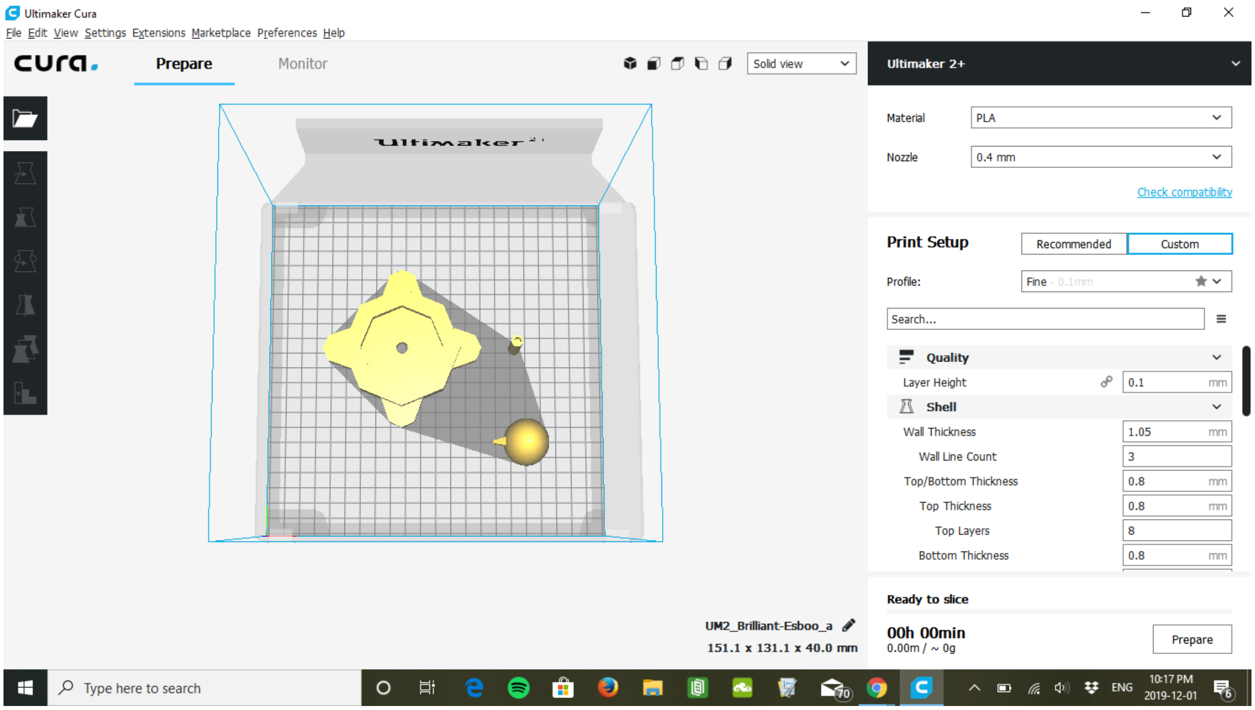

Figure 9 3D model of compass components (top view)

- The potentiometer was attached to a stepper motor, and the movement of the potentiometer changed the direction of rotation of the motor. The motor was attached through the shaft seen in Figure 9, so the pointer of the compass moved along with the motor, indicating the direction as either North, South, East or West.

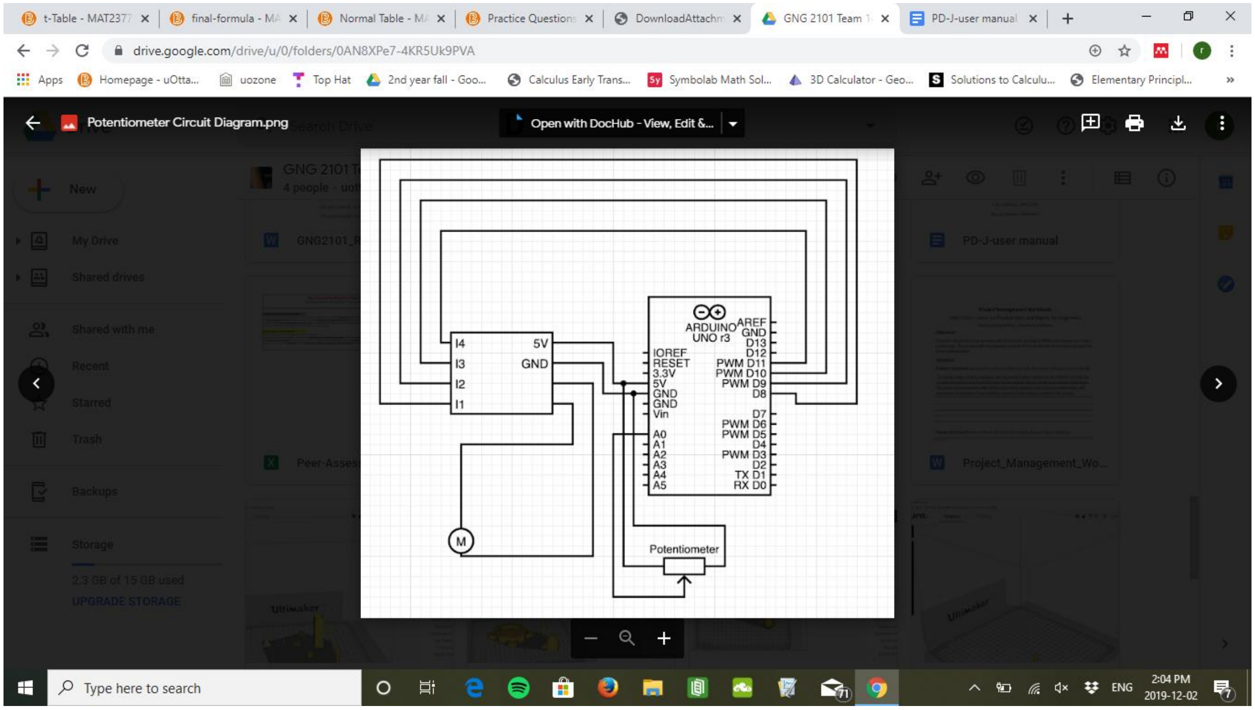

Figure 10 Potentiometer and Motor Circuit

3.0 Health and Safety Guidelines

The accessible control involved complex circuitry and wiring, which presents a potential hazard for those who are not operating the control panel correctly. Users should avoid operating the control panel in a wet or damp environment, as the moisture could interfere with the circuitry and potentially cause damage or injury. In addition, no food or drink should be handled around the device to reduce the risk of the device being damaged.

The control panel should be placed on a stable base no larger than 1.5 meters high, that can hold at-least 20 pounds and is at-least 600mm in width and 400mm in height. This is to reduce the risk of the device falling, causing damage, injury, or possibly death. Therefore, handling should be done with care.

The device is running on an Arduino UNO board which can handle between 7 - 12V of power, with the possibility of pulling power from a USB A or DC power source. If a method of power is used that is greater than 12V there is a risk of frying the circuit and damaging the control panel.

The device should be stored indoors with temperatures ranging from -40 to 85 degrees Celsius. If temperatures deviate from this range, then the Arduino will fail to operate as intended.

4.0 Trouble Shooting and Technical Instructions

Technical aspects:

- The horn and the vibration buttons cannot be used at the same time
- The wheel must be turned slowly for the potentiometer to work properly. If turned too fast, the motor won't rotate
- Due to the use of an Arduino instead of a stronger micro controller (such as a raspberry pi), the speakers are at a lower volume.

Assembly Instructions:

1. Place MDF box on appropriate table**

** Appropriate table: A table that meets the museum's accessibility standards (at least 610 mm height, 760 mm length, 480 mm width)

2. Insert Arduino's USB cable to power source (ideally a laptop or a power source no larger than 12 volts)
3. Test to ensure all buttons and the potentiometer are working properly
4. Device is now ready to use

5.0 Conclusions and Recommendations for Future Work

The wheel currently turns a GPS for there to be a tactile interaction for those who are visually impaired, but in the future a screen could be added to more accurately depict modern day precision agriculture techniques. The speakers are all powered through an Arduino Uno, so the sound is relatively low. In the future, a stronger speaker could be used to ensure that the sound of the horn and reverse can be heard in the loud museum environment. The clients also mentioned installing an audio jack so that those with auditory impairments can plug in their personal earphones/headphones so that they could better hear the various auditory feedbacks from the control panel. Due to time and budget constraints, this was not implemented, which is why it is under future work. Another interaction not found in our control panel is light interaction. The buttons that we used already have LED's inside, so if a stronger microcontroller was used, we could set up the light aspect of the buttons and have them light up when pressed. Not only would this allow for another form of interaction for young children, it would also allow those with auditory impairments to know when the horn is on and for those with low visual capabilities to be able to easily see what buttons are turned on.

In general, we completed all our main goals for this project. All the technical components, such as the vibrating wheel and the potentiometer, were completed. As seen in

Table 3 below, our final prototype met most of our target specs from the beginning of the project.

Table 3 Target Specs vs Prototype values

Target Specs				
Metric	**Target Spec**	**Units**	**Target Value**	**Prototype Value**
Color Contrast	At least 70% from background	%	≥ 70	70
Knee Clearance	At least a clear space of 610 mm x 480 mm x 760 mm (Height, depth, width)	mm	≥ 610 x 480 x 760	(Depends on the surface the client rests it on)
Clear Floor space	At least 760 mm x 1370 mm (width, length)	mm	≥ 760 x 1370	(Depends on the surface the client rests it on)
Controls Height	Under 915 mm	mm	≤ 915	~40
Viewing Object Height	Must be at around 1036 mm for children when 2 m away	mm	1036	(Depends on the surface the client rests it on)
Button size	At least 75 mm x 75 mm (square) or 75 mm in diameter (round)	mm	75	56

Button Shape	All buttons must be different shapes	mm	75	56
Volume Range	Reaches up to 20 dB above ambient volume (45 dB taken as reference)	dB	≤ 65	<80
Text Font Size	Minimum text font height will be within 5-19 mm range	mm	10	15
Reach Distance	Forward reach distance must be within 508-915 mm for children	mm	≤ 915 mm	<800mm
Force Requirement for Controls	Must be less than ⅓ force of maximum user force, without requiring twisting motion	Relative	⅓ max force	⅓ mac force
Interaction Time	Interaction cycles should be < 30 sec	s	≤ 30	<25

Although there was room for more technical aspects, we understood that within the budget and time-frame given, it was better to stick to what we knew we could finish instead of trying to do more than what was feasible and getting overwhelmed at the end. Due to scheduling issues with our client, we ended up starting our final prototype later than expected. We learned that we should have communicated more with our client and between ourselves, since, if we had properly understood what our client wanted from the beginning, we could've started our final prototype earlier and had more time to implement more technical aspects. As mentioned above, we could've added LED's or other interactions, but didn't due to time constraints.

6.0 Bibliography

"Ingenium Accessibility Standards for Exhibitions." *Accessibility Canada*, Ingenium, 3 June 2019, https://accessibilitycanada.ca/wp-content/uploads/2019/07/Accessibility-Standards-for-Exhibitions.pdf.

APPENDIX A: Design Files

Figures A.1 – A.4 are screen shots of the PDF files one can use to replicate the board pieces. All pieces were laser cut from 24 × 18 × ¼ (length, width, depth) inch MDF board. All necessary files can be found on MakerRepo: https://makerepo.com/clairediprisco/gng-2101-accessible-tractor-a14

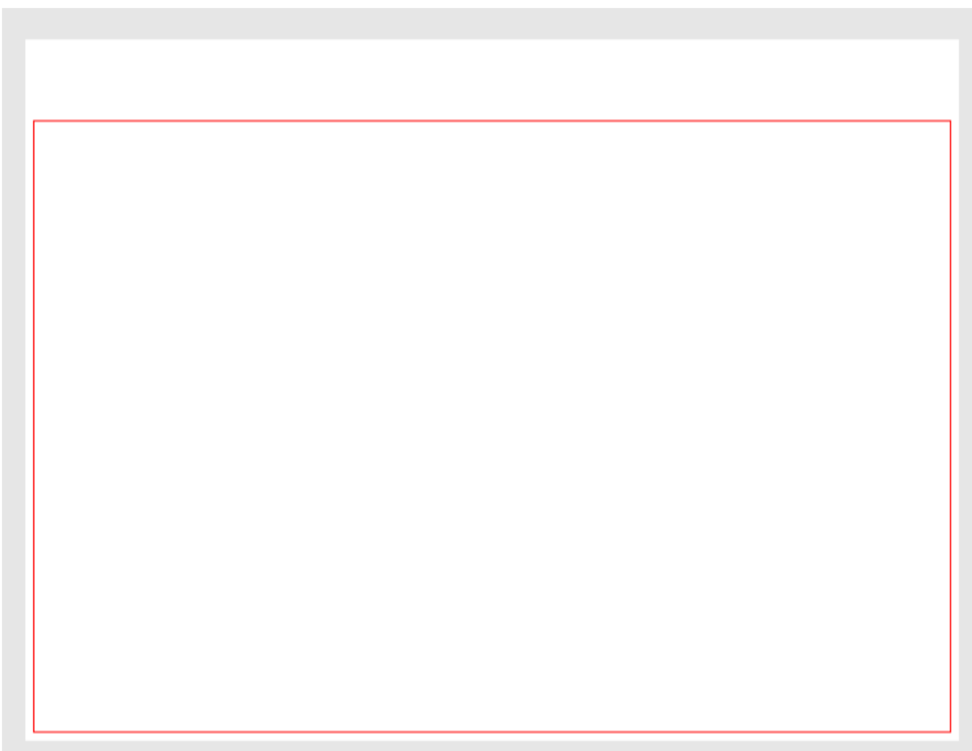

Figure A.1 Board base piece PDF file

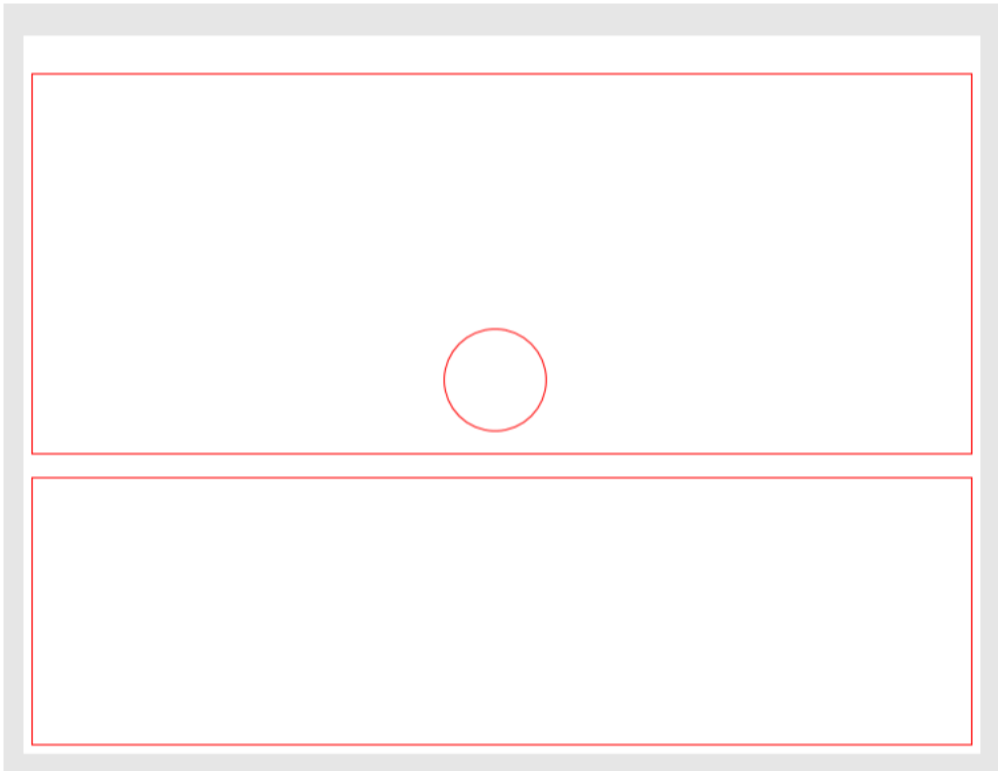

Figure A.2 Board front and back pieces PDF file

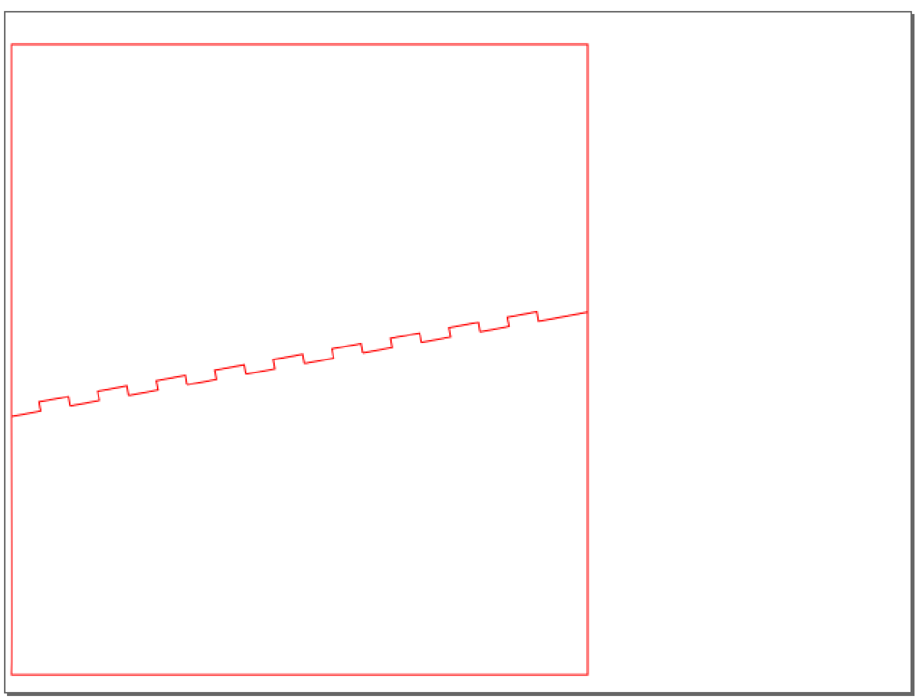

Figure A.3 Board side pieces PDF file

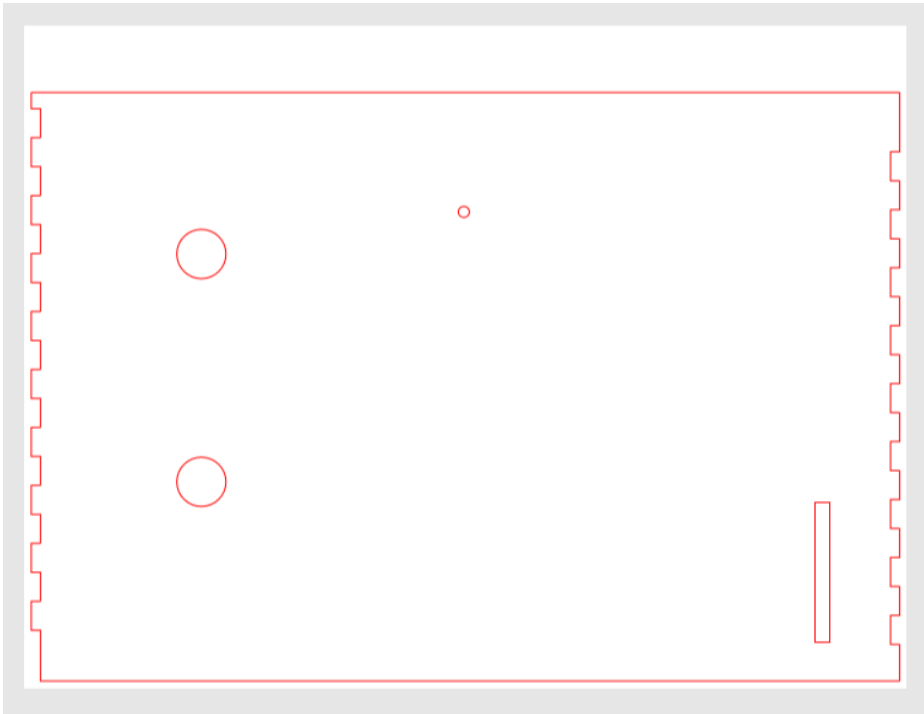

Figure A.4 Board top piece PDF file

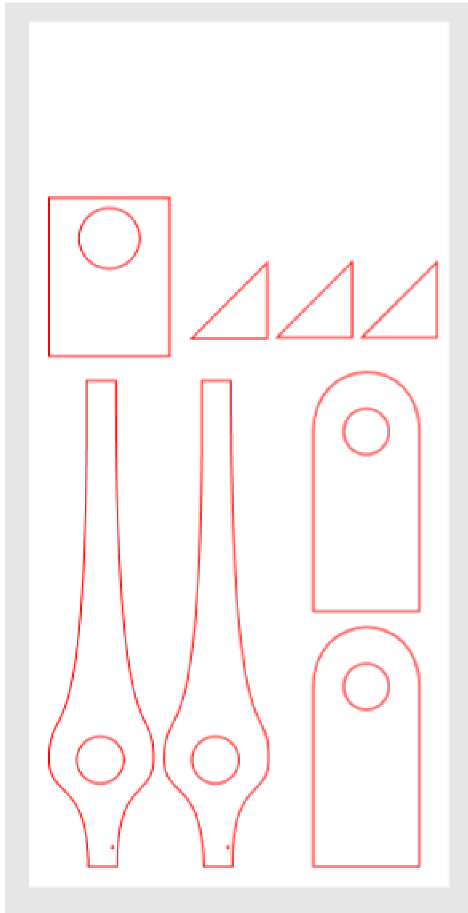

Figure A.5 PDF file to laser cut lever (bottom left), shaft supports (bottom right), and button support (top)