GNG 2101

Design Project User and Product Manual

Portable Table

Submitted by:

Team N.F.T (Neatly Folding Table) C1.3

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Table 1. Acronyms

Acronym	Definition
UPM	User Product Manual
PT	Portable Table
MDF	Medium Density Fibreboard

1 Introduction

This User and Product Manual (UPM) provides the information necessary for product users to effectively use the Portable Table (PT) and for prototype documentation.

This system was designed to provide an adjustable and highly portable table for use on the go for reading and light work. In addition, the system was designed in such a manner as to avoid he need for any gripping, twisting, repetitive motions or and other motions that required fine motor control.

The intent of this document is to provide the necessary information for any users to operate the PT safely and competently, as well as the information necessary for any groups looking to iterate, improve upon or to manufacture their own PT.

To that end this document will first focus on a system overview as well as necessary safety warnings, it will then cover operation and troubleshooting, finally it will cover documentation of design, manufacture and assembly, as well as notes from the designers on future work.

It should be noted that at the conclusion of this project, the PT was firmly in the prototype stage, as such the device and operation thereof detailed within this document does not meet the design specifications listed and should not be used for the final purpose. The final prototype constructed was done so with the purpose of verifying the user experience operating the device.

2 Overview

The client for this project had a requirement for a table that could be transported easily by a single person, support their reading or work material and, due to their condition, facilitate frequent position changes easily. Further, in order to allow the system to be accessible to the client, adjustment systems requiring gripping, twisting, repetitive motions or and other motions that required fine motor control were avoided.

In practical terms, the system needed to be able to fit within a backpack (or similar sized vessel), be provide multiple levels of height and tilt adjustment, and be light enough to be carried alongside a standard student load.

The system designed in this project incorporates portability, stability and adjustability and allows for accessibility by using mechanisms for adjustment that require no fine motor movements, as all adjustments can be made by pushing or pulling on members.

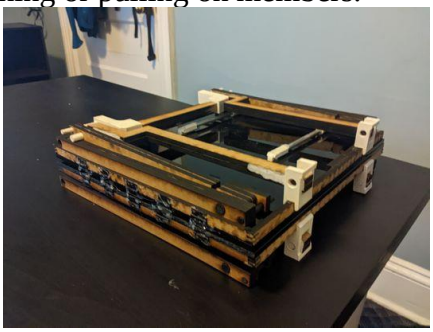

Figure 1: Final Prototype - Folded

The PT prototype designed is composed of two subsystems, the tabletop and leg systems. The leg subsystem is a folding structure with three tiers. Each level can fit within the one above when not deployed and swing out to increase table height. The legs lock into position through the use of pins which press fit into slots cut into the above tier as the legs rotate out and require user force to return to position.

The tabletop is composed of a tabletop hinged on a frame which has grooved slots along the inside. A crossbar is hinged on the underside of the table, by lifting the tabletop and moving the crossbar to the desired slot, the tilt of the table can be adjusted.

The leg system is secured to the tabletop system by a hinge attached to the frame. Two tabletops are secured together with hinges to create a full folding table of two tabletops and two leg systems.

At the current design stage, the legs and frame of the tabletop are made of Medium Density Fibreboard (MDF), the joinery and leg hinges are 3D printed PLA, finally the tabletop is acrylic, remainder of the hinges are brass, the crossbar is aluminium as the bottom most spanning member of the legs.

Cautions & Warnings

Please be aware, that the PT prototype uses multiple folding members which creates numerous pinch points during operation. Be aware, and control the motion of the system in use, especially if multiple users are present.

3 Getting started

3.1 Configuration Considerations

There are three functions of the PT. They are the adjustable tilt, adjustable height, and the folding table. Setting up and taking down the PT is covered in this section. An in-depth breakdown of each function is available in the next section: Using the System.

3.2 Setting Up the table

To set up the table start by placing it on a surface.

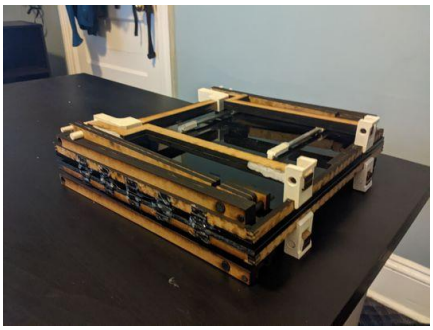

Figure 2: The Table in its Smallest Form

Next, Unfold the table by grabbing the upper half and folding it outwards.

Figure 3: Folding the table

After unfolding the table, Flip the table over and pull out the legs to the desired height. Then, Flip the table back over and assembly is complete.

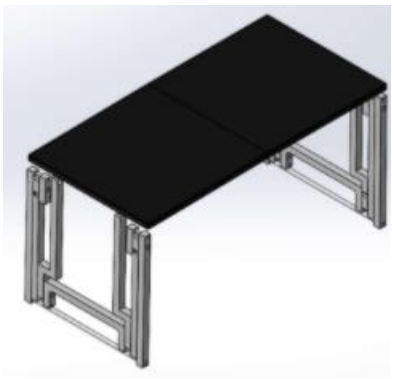

Figure 4: Assembled Table

3.3 Using the Table

How to use the table will be covered in the next section.

3.4 Putting Away the Table

To put away the table start by flipping the table, so the surface of the table is facing down. Then, begin folding the legs inwards from their original perpendicular position. At this point the legs will flush to the table frame. Now, flip the table over again and fold either side on top of the other. Your table is now in its smallest form and is ready for storage or transportation.

4 Using the System

The following sub-sections provide detailed, step-by-step instructions on how to use the various features of the portable table

Adjusting the Legs

Adjusting the legs requires a simple pulling motion. The legs begin together fully folded resting on the frame of the table.

Figure 5: Fully folded legs

To make the change to the first level simply lift the legs until they are perpendicular to the table surface.

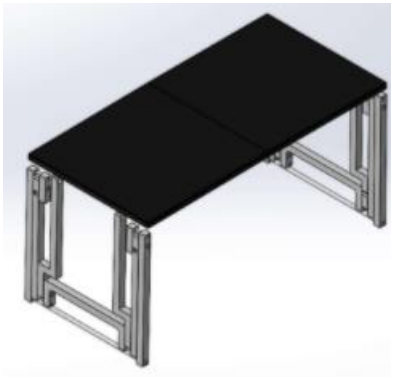

Figure 6: Legs folded out

To reach the second level of adjustment pull the outer legs out and click the white retaining pin into the slot. When extended the legs will click into place.

Figure 7: The second level of adjustment

To reach the final level of adjustment the same motion is used. Pull the final layer of legs out and click the retaining pin into place. The legs will once again lock in place at the max height.

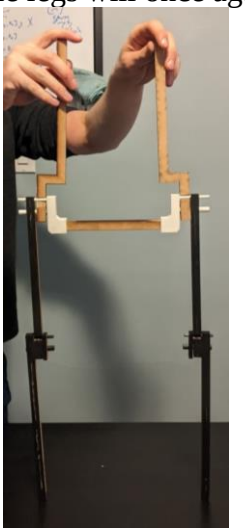

Figure 8: Fully extended legs

To take down the legs push on the leg in the opposite direction and the pin will unclick allowing the legs to fold in. Repeat this process for each level until fully folded.

Adjusting the Tilt

Adjusting the tilt requires a simply lifting motion. there is an aluminium bar that rests within the frame of table and to set a level of tilt, place the bar in the notch of the frame.

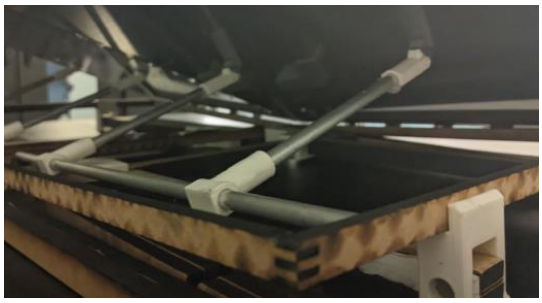

Figure 9: The bar resting in the frame

To remove the tilt, lift the bar then set the tabletop down on the frame.

Folding the Table

Folding the table is a straightforward motion with no hatches or latches. To fold simply grab the desired side and lift until it is on top. To unfold the table, do the reverse. Lift the desired side and open. This motion is shown in the screen shots below.

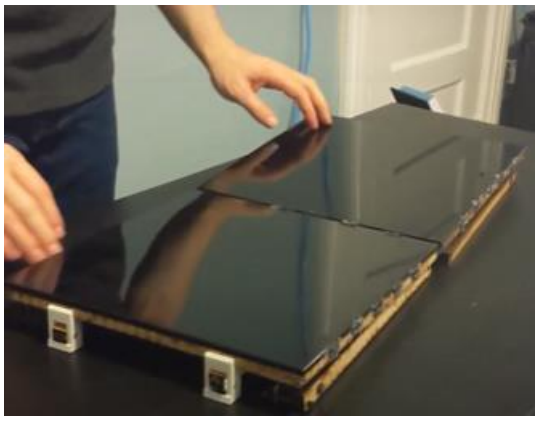

Figure 10: Table fully open

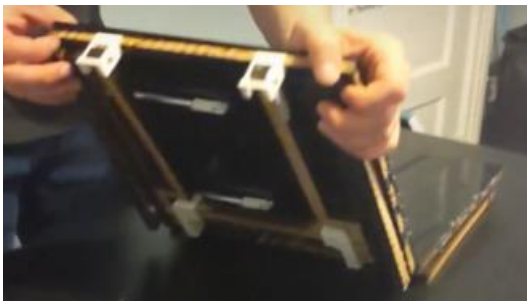

Figure 11: Folding the table

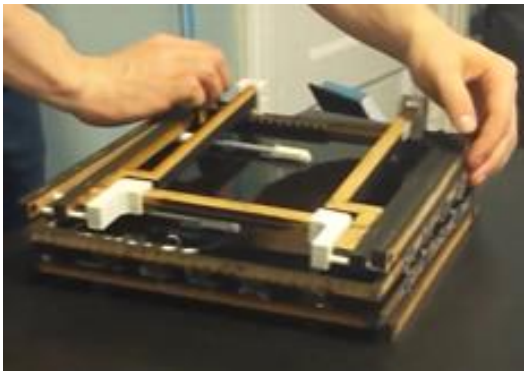

Figure 12: Table fully closed

5 Troubleshooting & Support

As this is a prototype product, at present all functionality has not been fully tested and unforeseen errors may occur in usage.

Maintenance

As this is a prototype built for limited experimentation, considerations for maintaining the device have not been considered to date.

Support

This design is provided as documentation for any teams attempting to build upon the work done to date on the portable table challenge. This is intended as a handoff document, no support shall be provided in addition to this document, the associated file, and the project repository.

6 Product Documentation

6.1 Tabletop Sub-assembly

i. BOM (Bill of Materials)

The following is a compilation of all required materials to manufacture the current iteration of the prototype.

Table 2: Tabletop BOM

#	Item Name	Quantity	Description	Approx Price	Source	Preferable Alternative
1	Black Acrylic	1	24”x12”x1/8” sheet. To be used for both halves of tabletop.	$13.00	MakerStore	Carbon Fibre Sheet
2	¼” Aluminium Rod	6 feet	For table adjustment mech	$14.00	McMasterCarr	None
3	MDF Sheet	1 sheet	12”x24” sheet. For table frame and legs.	$10.50	MakerStore	Aluminum
4	PLA Filament	n/a	For PLA printed parts	n/a	Makerspace or personal	None
5	Hinges	12	For securing tabletop	$10.19	Amazon	Larger Hinges Preferable
6	Superglue	1	For mating components to tabletop	$6.98	Home Depot	Physical Joiners, Like Screws Preferable
7	Wood Glue	1	For assembling the frame of the tabletop.	$4.49	Home Hardware	None

ii. Equipment list

Tools and Equipment required to manufacture this are as follows:

Table 3: Tabletop Equipment List

#	Equipment	Use
1	Laser cutter	Used in the cutting of the acrylic tabletop, and frame components.
2	Cutting Device: Hack-saw, Band-saw, etc.	Used in the cutting to size of aluminium rods.
3	Clamps	Used to hold together components during gluing.
4	Finishing tools: Files, Sandpaper, Deburring tool.	Used to refine sharp edges.

iii. Instructions

The first stage of the manufacturing process involves the machining, cutting, and printing the individual components to prepare for assembly. For this section part numbers will refer to the labels used in the tabletop sub-assembly drawing (PT-00-03 TABLETOP ASSEMBLY.pdf). For all components double the number to be made based off the drawing, as there are two tabletop sub assemblies to be made.

1. 3-D printing parts takes a considerable amount of time so we will start with the manufacturing of those parts first. Parts 2, 3, 5 are all 3D printed. These components will need to be sliced using software, Cura is useful for this, but slicer chosen will depend on the printer being used. Medium settings are with high infill are recommended. Additionally, due to overhangs support material should be used, and a raft for adhesion is recommended due to the small size of components. Use the the Finishing tools to allow for better fitting between parts.

2. The next step is the manufacturing of the aluminum rods used. There are two different sizes needed, one for the crossbar and one for the leg. Taking the ¼” Aluminium rod cut 4 sections of rod to 6” for the legs of the tabletop subassembly (this is enough for both halves of the table). Cut the remaining rod into two sections 11.5” long. Cutting operations on metal often leave sharp edges, be sure to use deburring tools and files/sandpaper to remove edges and burrs.

3. Next, we prepare the MDF components for construction of the frame. This needs to be done for all parts of the Frame_Subassm. Detailed instructions on the use of the laser cutter can be found on MakeRepo.

4. The final component of the Tabletop subassembly is the acrylic table top. Cut the acrylic sheet into two even halves. If using a differently sized piece of source material cut a 1”x1” for each tabletop half.

5. We then begin the assembly of components First we will glue together the square frames. The teeth cut at the ends of each member mesh together:

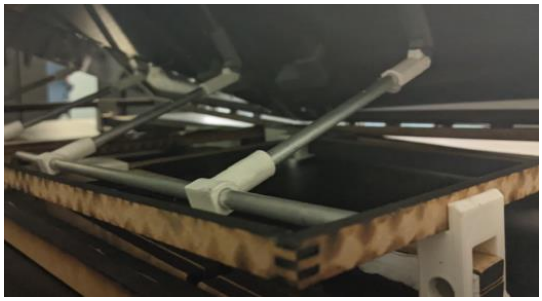

Figure 13: Tabletop Mechanism

Add glue to the inset of these teeth and press together securing via clamps while the glue sets, for this step follow your brand of wood glues instruction. Repeat this for each corner of each half.

6. Next, we glue the Slots component to the inside of each side of the frame, align it so the bottom of the Slots is flush with the bottom of the frame and such that the largest slot, meant for when the table is fully folded, is pressed to the back of the frame as seen below.

Figure 14: Retaining Bracket

7. We then prepare the tabletop, using the CAD as a guide Superglue the Leg_AttatchV2 to the underside of the acrylic. Following this, mate the Leg_Adapter with Leg_AttachV2, pin the two together using a printed pin.

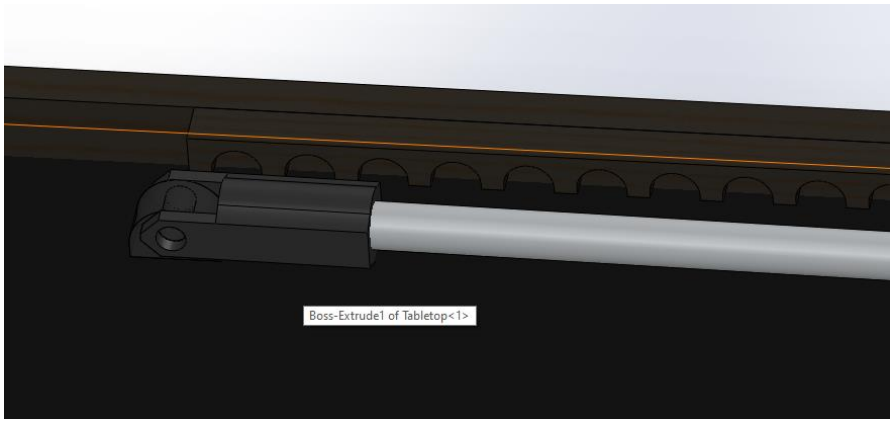

Figure 15: Tabletop Support Legs

8. The Leg_V2 component will then slot into the Leg_Adapter, this should friction fit but may be additionally glued for additional strength. The free side of the rod can then be mated with the Crossbar_Adapter. The Crossbar_V2 will then slide through the free hole of the Crossbar_Adapter.

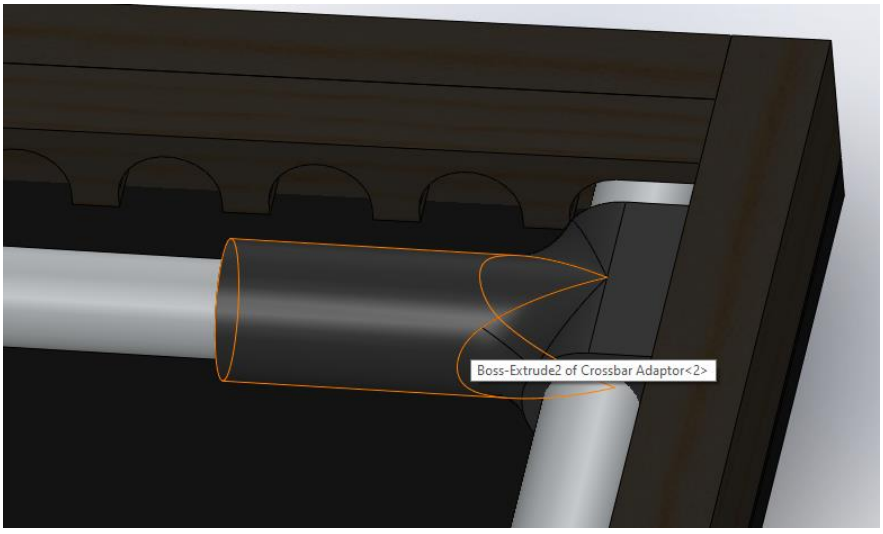

Figure 16: T-Adapter

9. The penultimate step is attaching the tabletop to the frame. Using the Superglue, glue the edge of the acrylic opposite of the Slots to the frame with a drop of Superglue on

each side of the hinge. Repeat this for several hinges, this will allow us to distribute the load on the hinges, for each side of the hinge clamp the hinge as the glue sets. While using the Superglue take care to not glue the hinge shut as this will put undue torque on it when operating later.

10. Lastly, glue hinges to the sides of either acrylic top using the Superglue, repeat with the remaining hinges allowing the glue to set after each. This allows the table to fold into its compact form.

Figure 17: Middle Hinge

6.2 Legs Sub-assembly

6.2.1 BOM (Bill of Materials)

The following is a compilation of all required materials to manufacture the current iteration of the prototype.

Table 4: Legs BOM

#	Item Name	Quantity	Description	Approx Price	Source	Preferable Alternative
1	PLA Filament	n/a	For PLA printed parts	n/a	Makerspace or personal	None
2	Wood Glue	1	For laminating the wooden members	$4.49	Home Hardware	None
3	MDF Sheet	2 sheet	12”x24” sheet. For Leg members	$10.50	MakerStore	Aluminum

iv. Equipment list

Tools and Equipment required to manufacture this are as follows:

Table 5: Legs Equipment List

#	Equipment	Use
1	Laser cutter	Used in the cutting of the acrylic tabletop, and frame components.
2	Drill Press	Used in the drilling of holes in some leg members
3	Clamps	Used to hold together components during gluing.
4	Finishing tools: Files, Sandpaper, Deburring tool.	Used to refine sharp edges.

v. Instructions

The first stage of the manufacturing process involves the machining, cutting, and printing the individual components to prepare for assembly. For this section part numbers will refer to the labels used in the tabletop sub-assembly drawing (PT-00-02 LEG ASSEMBLY.pdf). For all components double the number to be made based off the drawing, as there are two leg sub-assemblies to be made.

1. As with previously we begin with 3D-printing, the parts needed to be printed for this sub assembly are Parts 2, 4. Additionally, we need to print 2 parts each of ADAPTER, and ADAPTER2. These parts, as they are load bearing, should be printed with high infill and as previously with supports and a raft.

2. Next begin manufacturing the members of the legs. Begin by arranging the members such that the holes are shown (and therefore will be cut) for PT-01-02 MIDDLE LEG, and PT-01-01 LARGEST LEG, orient PT-01-03 BASE LEG such that the holes are not shown (It should look like a zigzag in the cutting image) as they will be drilled in a later step. An example is given below.

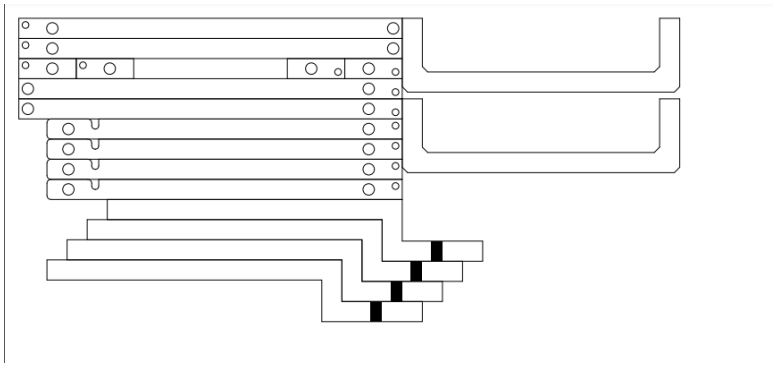

Figure 18: Legs Cutting Template

3. Each of these ¼” components will then be glued together taking care that holes and edges align. Follow the instructions of your brand of wood glue, clamping while the glue sets.

4. All members being laminated, one final drilling operation must be conducted on the PT-01-03 BASE LEG, (this is the “zigzag” member). It is recommended to print a drilling template from the part drawings to ensure proper alignment of the holes. Three holes must be drilled, the two larger holes must be drilled with a diameter of 5 /16” the smaller hole which will be drilled with a diameter of 3/16”. Consult the CAD for precise hole placement. It is recommended to drill smaller pilot holes for the large holes to prevent cracking of the members.

5. With all individual components created begin assembly. First create the sub-sub-assembly of the first-tier cross brace. Make sure that the adapters on each side are different, one must be ADAPTER, and one must be ADAPTER2.

Figure 19: Legs Crossbrace

6. Next, fit the larger peg of the adapters through the holes of the PT-01-03 BASE LEG, take care to correctly align the off-centre peg to the side with the slot to ensure correct mating.

7. Following this on each side of the current assembly to the unpinned hole of the PT-01-02 MIDDLE LEG. Through this hole press fit one of the large pins printed in step 1. On either side of this member also fit on one of the support members and one of the PT-01-01 LARGEST LEG. A small pin should be pressed through the small hole of both the support bracket such that when you spin the largest leg the small pin will slot into the middle legs slot. It is recommended to consult the CAD for a 3-D depiction of these joints while assembling due to the complexity.

6.3 Testing & Validation

This tabletop subassembly was tested qualitatively based off the ease of use of the mechanism primarily. Additionally, we verified that all 15 tilt possibilities were usable, finding they were. We additionally tested the action of the tilt mechanism which while working has some issues. The main issue with the movement of the tilt is that due to the poor rigidity of the MDF used for the frame, the frame tends to not be perfectly square, this warping makes it difficult to easily use the mechanism as the crossbar can get stuck underneath the frame. Additionally, the warping can "clamp" the crossbar due to the flex in the frame making manipulating the tilt difficult.

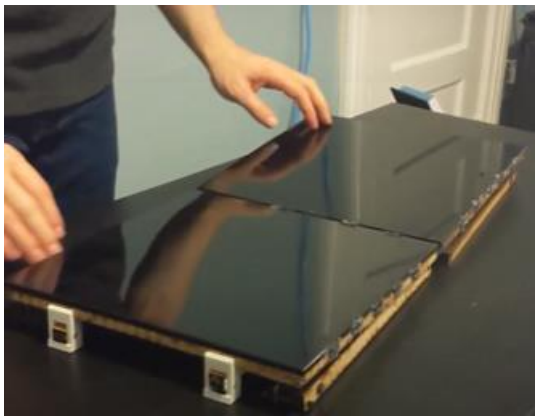

Figure 20: Tabletop Warping

Changing to the recommended aluminium frame would likely remedy this. The table in it's current iteration cannot actually support it's own weight due to the poor rigidity of the MDF, should you want to practically use this design the material change must be made. Testing also reveled many issues with the hinges used in the tabletop subassembly. We would recommend replacing the joints of the hinges to frame/table surface from an adhesive to a physical fastener such as a screw. We would also recommend larger and stronger hinges, potentially the length of the joining edge. Another change to make would be to change the acrylic of the tabletop surface to the suggested carbon fibre or more economically MDF, this would allow for a better material to screw into. Changing from acrylic would also reduce the weight of the overall system.

The leg subassembly was primarily qualitatively tested for ease of use of the mechanism. With regards to this we were very satisfied with our performance, the mechanism was easy to

manipulate with no fine motor movements. We didn't test the amount of load that could be held as our table full assembly was not self-supporting. We did however have some tolerance issues with the hand drilled holes of step 4.

Figure 21: Legs Tolerance

This is due to the high required tolerance to get a good joint between the retaining pin and the slot, this led to very little retention in the mechanism in that tier of the legs. Going forward we would recommend reworking the design of PT-01-03 BASE LEG such that the holes can be laser cut allowing for a much higher level of tolerance and a better fit to the mechanism. Like with before we recommend adjusting material, changing to aluminum tubing, to allow for higher strength in the legs.

7 Conclusions and Recommendations for Future Work

This project has provided an excellent chance to approach design with an accessibility first mindset, as well as to learn to design under time and budgetary constraints. From this experience, several lessons have been learned that can be incorporated into any future attempts at the project.

1. While difficult in the beginning of the project, when information and experience is limited, it is beneficial to strictly define the final goal of the project so as to be able to clearly set stages of development. As was learned in this experience, leaving ambiguity in these definitions can lead to suboptimal choices that must be dealt with in later stages of development. Further to this, be willing to adapt these plans as the project progresses.
2. Keep prototype iteration time in mind when designing, as an excellent design may be impossible to act upon if manufacturing considerations are not taken into account. Keep in mind the manufacturing resources available as well, and their availability if they are communal. Finally, remember to add delay time into prototype iteration time calculations for unexpected delays or setbacks.

Based off of these lessons, and on previously planned future work, the following steps are recommended for any teams continuing this project going forward.

1. Manufacturability of certain elements of the design can stand to be improved. Particularly in the case of members where multiple operations are required to manufacture the part (i.e. a leg member where laser cutting is required followed by hole drilling on an alternate side). Complex parts increase manufacturing difficulty and increase prototype iteration time. Altering the design such that more members can be manufactured as a 2-D part (where operations are only done in 1 plane) is recommended.
2. Changing the materials used to the recommended carbon fibre and aluminium is recommended such that the strength of the design in actual conditions can be evaluated.

3. Modifying the central folding hinge between the two tabletop subassemblies is recommended for table stability and ease of setup (this would eliminate the need for the current clamps). Moving the hinges from the tabletop to the frame and reversing the direction of folding would accomplish this, however it would require a redesign of the leg subassembly mounting. The future past this prototype was a double hinge to allow the leg to fold onto the tabletop while still deploying from the frame.
4. Given the current unused space within the frame, it is recommended to test cross members on the frame to increase tabletop rigidity.

APPENDICES

8 APPENDIX I: Design Files

Table 6. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
GNG 2101 - C13 - NFT	https://makerepo.com/Owen/1193.gng-2101-c13-nft-	March 28, 2022
Bill of Materials	https://makerepo.com/Owen/1193.gng-2101-c13-nft-	April 24, 2022
Portable Table CAD	https://makerepo.com/Owen/1193.gng-2101-c13-nft-	April 24, 2022
Portable Table Laser Cut Template	https://makerepo.com/Owen/1193.gng-2101-c13-nft-	April 24, 2022