

Portable Testing Chamber Assembly Protocol

Mueller Lab

Jason Chen, Michele Kaluzienski, Jenna Mueller,
Tri Quang, and Surabhi Singh

UPDATED 5/29/24



Introduction

The Portable Testing Chamber (PTC) is designed to facilitate essential laparoscope characterization imaging in a standardized manner, eliminating the need for expensive optical tables or associated high-cost components. The PTC ensures reliable testing conditions by effectively blocking out external light and providing uniform internal lighting. With these goals in mind, we have implemented iterative optimization of dimensions, materials, design, and LED lighting. In contrast to alternatives like Thorlabs' XE25C9 model, which can exceed \$300 in cost and lacks integrated lighting, our solution offers a cost-effective, fully illuminated, and seamlessly compatible option for a variety of laparoscopes. This document outlines the required materials and the steps to assemble our PTC.

Complete List of Materials

- (TC000-1) Optical Breadboard
- (TC000-2) Rail, 6"
- (TC000-3) Rail, 9" x2
- (TC000-4) Rail Carrier, 1" x3
- (TC000-5) Post Holder, 3" x2
- (TC000-6) Post for Scope, 6"
- (TC000-7) Post for Target Holder, 3"
- (TC000-8) Target Mount CH2B
- (TC000-9) Mini Extension Rods MS3R x2
- (TC000-10) Adhesive Metal Plates x
- (TC000-11) Rail, 12"
- (TC000-12) LED Array x2
- (TC000-13) White Styrofoam Board w/
adhesive side, 12" x 16" x4
- (TC000-14) White Styrofoam Board w/
adhesive side, 12" x 12"
- (TC000-15) Black Cardstock
- (TC000-16) Chamber Opening Adapter x2
- (TC000-17) Scope Clamp, w/ $\frac{1}{4}$ "-20 screw
- (TC000-18) C-Nuts x2
- (TC000-19) Screws, 8-32, 0.25"
- (TC000-20) Screws, $\frac{1}{4}$ -20, 0.375" x9
- (TC000-21) Screws, $\frac{1}{4}$ -20, 0.50" x6
- (TC000-22) $\frac{1}{4}$ " washers x4
- (TC000-23) M4 Washers
- (TC000-24) Tape
- (TC000-25) Base Frames x4
- (TC000-26) Ceiling Frames x4
- (TC000-27) Frame Connectors x4
- (TC000-31) 29cm Brush Strip
- (TC000-32) 28cm Brush Strip

Complete List of Tools

- (TC2000-101) Digital Level
 - (TC2000-102) AA Batteries for LED Array
 - (TC2000-103) Screwdriver Hex Key Set ($\frac{3}{16}$ " and $\frac{7}{64}$ " piece)
 - (TC2000-104) Pliers
 - (TC2000-105) Ruler
 - (TC2000-106) Scissors
 - (TC2000-107) Pencil
 - (TC2000-108) Box cutter
 - (TC2000-109) Gaffer Tape
 - Add notes about putting the tape around all the styrofoam board edges
-

Build Process

Rail Assembly

1)

Materials Needed

- (TC000-3) Rail, 9" x2
- (TC000-1) Optical Breadboard
- (TC2000-103) Screwdriver Hex Key Set ($\frac{3}{16}$ " piece)
- (TC000-20) Screws, $\frac{1}{4}$ -20, 0.375 x4

Attach both 9" rails onto the portable optical breadboard at position 1 and 2 (see positions labeled below in Figure 1). Secure two screws to each rail at the circled positions (as shown in Figure 2). Make sure the two rails line up approximately end-to-end on the left side and parallel to each other. Screw down the rails from the top down, ensuring the cap of the screw sits within the counterbore, not protruding from the rail. The final setup should look like Figure 3.

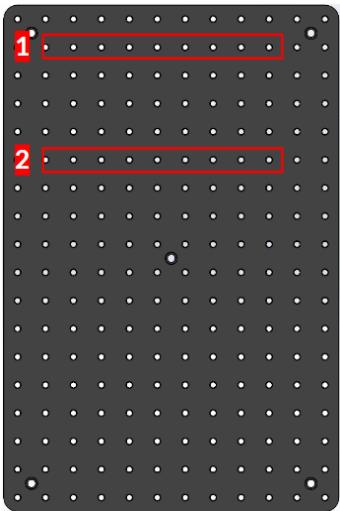


Figure 1

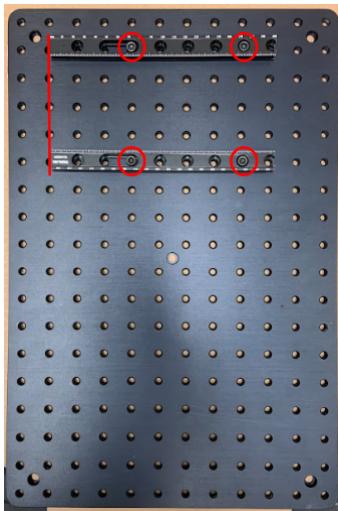


Figure 2

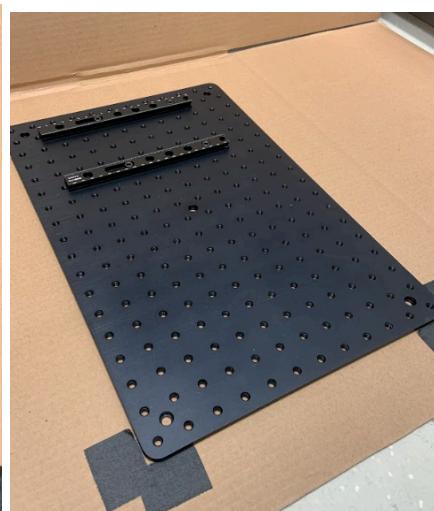


Figure 3

2) This step is IMPORTANT.

Materials Needed

- (TC000-18) C-Nuts x2
- (TC000-20) Screws, 1/4-20, 0.375" x1
- (TC2000-104) Pliers
- (TC2000-103) Screwdriver Hex Key Set ($\frac{3}{16}$ " piece)

We will prepare the C-nuts by roughly [tapping](#) them using the bolt. Use a set of pliers to hold the C-nut securely, as shown in Figure 4. Utilizing a $\frac{3}{16}$ " hex key, twist the screw into one of the two C-nuts. This action will carve threads into the C-nut, facilitating easier use in the future. Once the screw has passed through the entire C-nut, untwist the screw and repeat the process with the other C-nut. It's CRUCIAL to keep track of which side of the C-nut the screw was twisted into, as this will be the same side the screw will twist into in the next step. Flipping the sides will make it nearly impossible to twist in the screw, as you aim to retrace the threads created previously. Final result should resemble Figure 5.

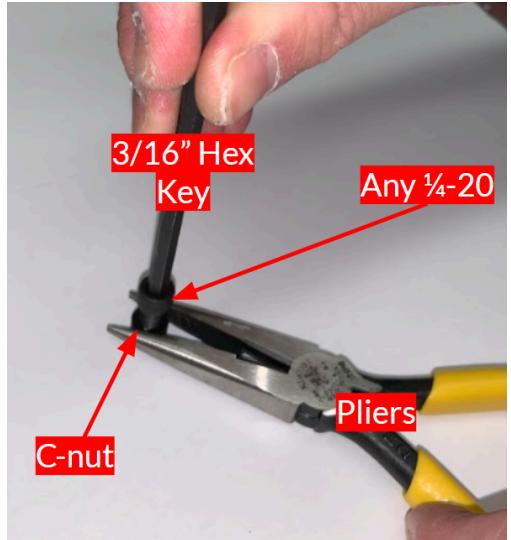


Figure 4



Figure 5

3)

Materials Needed

- (TC000-2) Rail, 6"
- (TC000-20) Screws, $\frac{1}{4}$ -20, 0.375 x2
- (TC2000-103) Screwdriver Hex Key Set ($\frac{3}{16}$ " piece)
- **Tapped** plastic C-nuts x2 (from Step 2)
- (TC000-4) Rail Carrier, 1" x2

The aim is for the 6" rail to slide perpendicularly to the sides of the two parallel 9" rails assembled in Step 1. Lay the 6" rail on top of the two rail carriers, paying careful attention to the orientations of the two rail carriers shown in Figure 6 and 9 (i.e., both set screw knobs are facing outwards). Ensure the hole of the rail carriers aligns with the holes at the ends of the 6" rail, as seen in Figure 7. Maintain this exact orientation of the rail and rail carriers over the next few steps. Insert a screw into one of the pre-aligned holes; the cap should sit within the counterbore in the rail as shown in Figure 8. Carefully flip the assembly 180 degrees onto its back as seen in Figure 9.

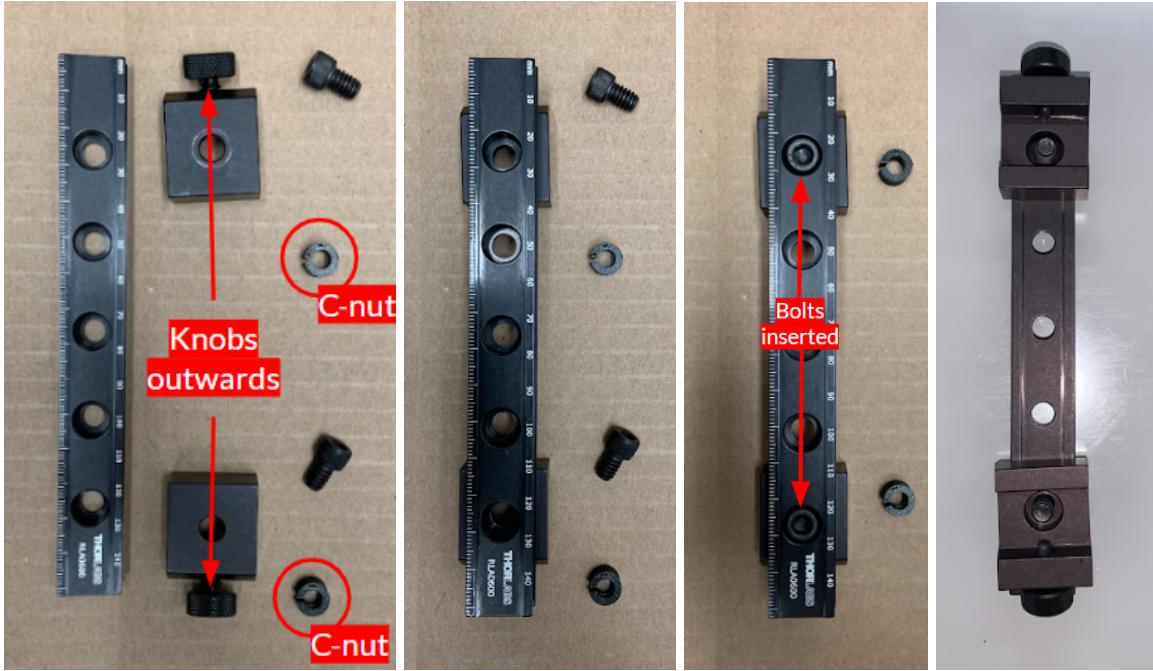


Figure 6

Figure 7

Figure 8

Figure 9

4)

This is a continuation of Step 3. Insert a C-nut we prepared in Step 2 into one of the holes with the bolt (it may be easier to do one rail carrier at a time, as shown in Figure 10 and 11 below). As mentioned in Step 2, be mindful of the side of the C-nut that the bolt screws into so that we can retrace the threads that were made. Initially, the C-nut will not sit flush in the counterbore of the rail carrier; this is okay. Use your finger to firmly push the C-nut against the bolt so that it will not rotate in the counterbore. Next, use the $\frac{3}{16}$ " hex key to screw the bolt into the C-nut while still pushing on the C-nut, but do not tighten it all the way; this will allow for easier adjustments in the next step. It may be easier to use your fingers to thread the screw into the C-nut first before using the hex key to fully twist them in. If you have trouble, repeat Step 2 and try again with a newly tapped C-nut.

Note that these C-nuts are plastic and should NOT be reused if disassembled. The final assembly should resemble Figure 12.



Figure 10



Figure 11



Figure 12

5)

Materials Needed

- Assembly from Step 4
- (TC2000-103) Screwdriver Hex Key Set ($\frac{3}{16}$ " piece)

Loosen the set screw knobs on both of the rail carriers. This will make it easier for the two carriers to slide onto the parallel rails. Carefully shimmy and slide the assembly onto the parallel rails. The setup should resemble Figure 13 and 14 below. Slide the assembly back and forth the entirety of the parallel rails as you gradually tighten both of the set screw knobs simultaneously. The assembly should become harder to slide around as the set screw knobs are tightened; that is okay. Since the screws in the assembly are still not fully tightened from Step 3, you can now make minor adjustments to the orientation of both rail carriers to optimize the ease of sliding the assembly on the parallel rails. The more aligned the rail carriers are with the rail it is sliding on, the easier it is to slide the assembly back and forth even as the set screw knobs are tightened.

Tighten the bolts once the desired orientation is achieved.

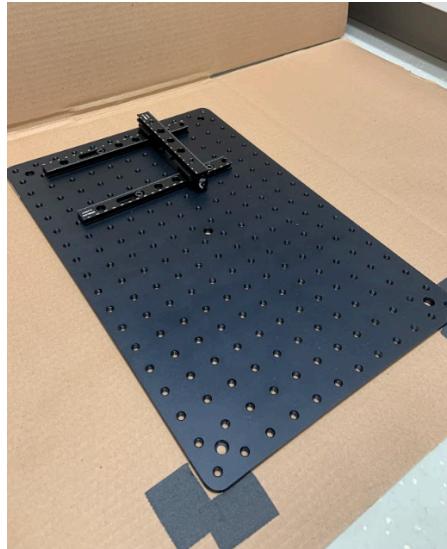


Figure 13

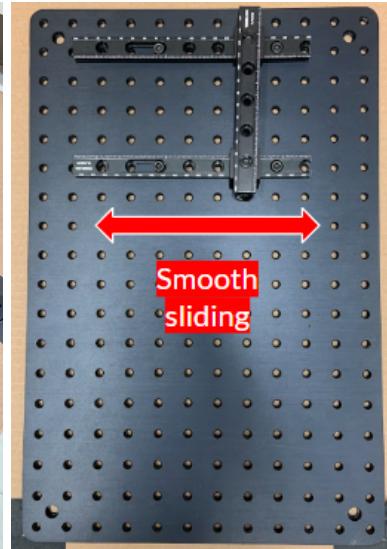


Figure 14

Target Mount Assembly

6)

Materials Needed

- (TC000-20) Screws, $\frac{1}{4}$ -20, 0.375" x1
- (TC000-4) Rail Carrier, 1" x1
- (TC000-5) Post Holder, 3"
- (TC000-7) Post for Target Holder, 3"
- (TC000-23) M4 Washer x1
- (TC000-8) Target Mount CH2B
- (TC000-19) Screws, 8-32, 0.25"
- (TC2000-103) Screwdriver Hex Key Set ($\frac{3}{16}$ " and $\frac{7}{64}$ " piece)
- (TC000-9) Mini extension rods MS3R x2

Note that the target mount should have two additional mini extension rods (MS3R) that we have already attached. If they are not attached, you will have to unscrew a set screw on one side of the mini extension rods and screw the mini extension rods onto the rods already connected to the target mount, CH2B. Insert the $\frac{1}{4}$ "-20 x 0.325" bolt through the rail carrier and screw it into the post holder. Insert the #8-32 x 0.25" screw through the hole of the target mount CH2B and insert it into the 3" post.

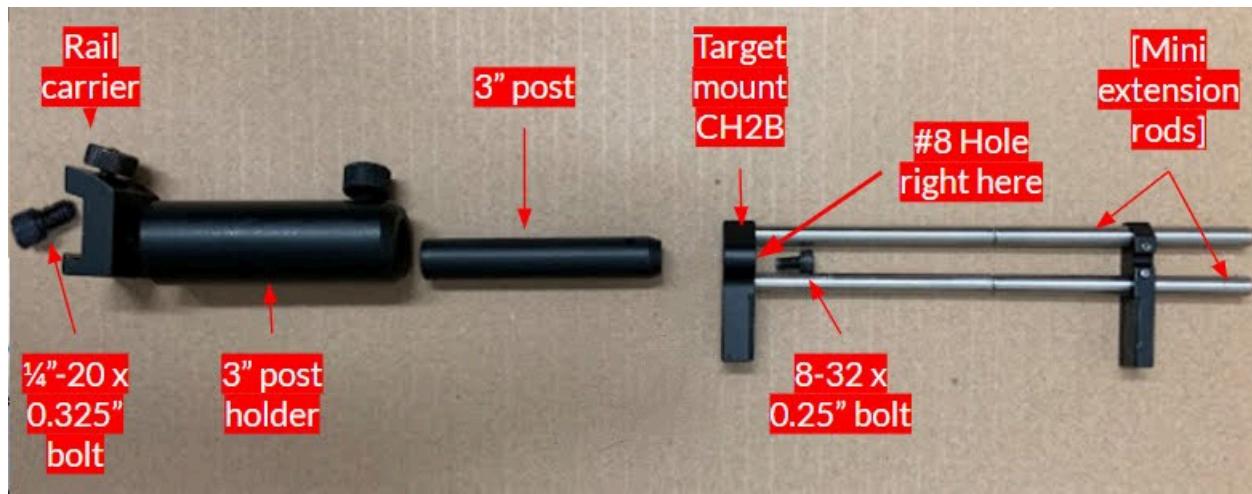


Figure 15

7)

This is a continuation of Step 6. Loosen the set screw knob on the 3" post holder and slide the post with the target mount CH2B all the way into the post holder. The setup should resemble Figure 16. Tighten the set screw knob on the post holder. Lastly, loosen the set screw knob on the 1" rail carrier, then shimmy and slide it onto the 6" rail assembled in Steps 3-6. The resulting setup should now resemble Figure 17 and 18.



Figure 16

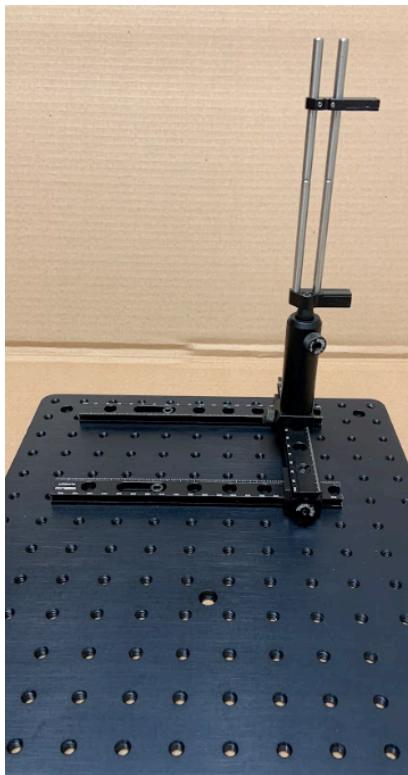


Figure 17

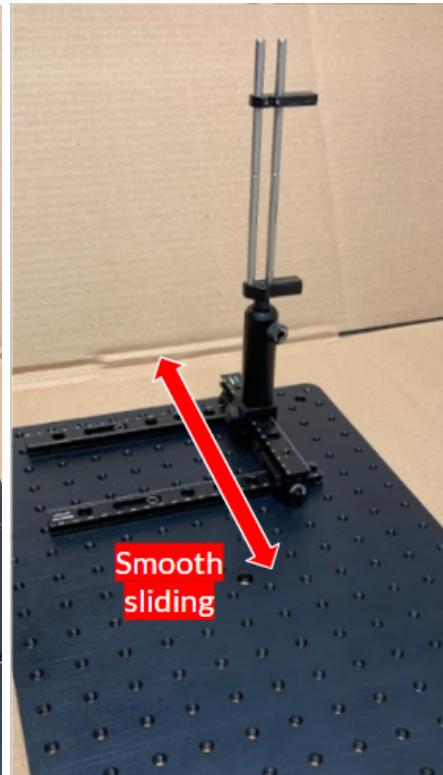


Figure 18

Scope Mount Assembly

8)

Materials Needed

- (TC000-20) Screws, 1/4-20, 0.375" x1
- (TC000-4) Rail Carrier, 1"
- (TC000-5) Post Holder, 3"
- (TC000-6) Post for Scope, 6"

- (TC2000-103) Screwdriver Hex Key Set ($\frac{3}{16}$ " piece)
- (TC000-17) Scope Clamp, w/ $\frac{1}{4}$ "-20 screw

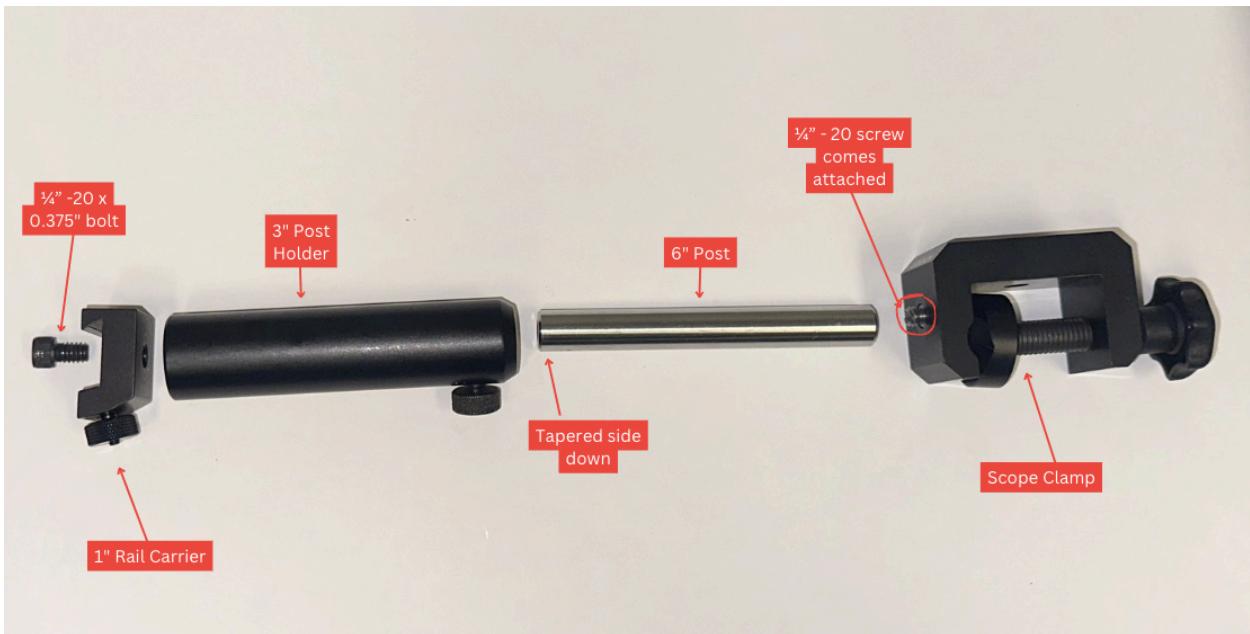


Figure 19

Insert the screw through the bottom of the rail carrier with the counterbore (see Figure 19 to visualize direction and placement of screw) and twist it into the post holder just like in the target mount; tighten firmly. Tighten the $\frac{1}{4}$ "-20 screw that comes with the scope clamp if it is not already, then screw the entire component onto the flat end (i.e., not tapered) of the post. Lastly, loosen the set screw knob on the post holder so you can insert the post with the scope clamp; tighten the set screw knob. The resulting assembly should resemble that of Figure 20.



Figure 20

9)

Materials Needed

- Assembly from Step 8
- (TC000-11) Rail, 12"
- (TC000-21) Screws, 1/4-20, 0.50" x2

You will bolt the 12" rail onto the edge of the optical breadboard closest to you. It should be able to sit flush with the breadboard when placed there. Use the holes on the farthest left and right to twist in one screw in each. Then, grab the scope mount made in Step 8 and loosen the side screw on the rail carrier. Now, from the right side, slide the scope mount onto the rail into the center. Tighten the side screw on the rail carrier. This is adjustable, so later during characterization of the scope itself, the location of the scope mount on the rail can be adjusted depending on the target view. For now, the center is fine. Final assembly should look like Figures 21 and 22.



Figure 21



Figure 22

Chamber Base Assembly

10)

Materials Needed

- (TC000-21) Screws, $\frac{1}{4}$ -20, 0.50" x4
- (TC000-22) $\frac{1}{4}$ " washers x4
- (TC000-25) Base Frames x4
- (TC000-27) Frame Connectors x4
- (TC2000-103) Screwdriver Hex Key Set ($\frac{3}{16}$ " piece)

This step will require four sets of chamber base sides (each set has one base frame, one frame connector, four $\frac{1}{4}$ "-20 x 0.5" bolts, a $\frac{3}{16}$ " hex key, and four $\frac{1}{4}$ " washers; some of these are shown in Figure 24 below). Part 1 is the base frame (larger corner) while part 2 is the frame connector (smaller leg of the frame). The male (protruding) side of part 2 fits into the female side of part 1; see Figure 24 to understand how the parts connect together. The eight parts will be reduced to four sets, each being a side of the chamber base. A full chamber base side is shown in Figure 25.



Figure 23

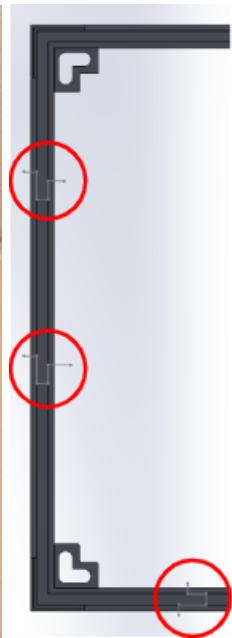


Figure 24

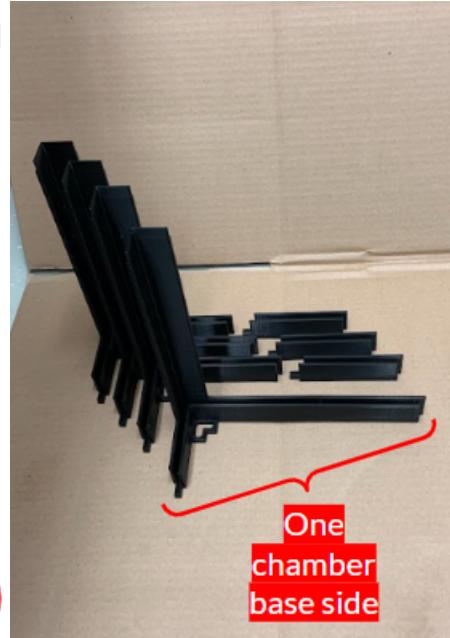


Figure 25

11)

This is a continuation of Step 10, using the four assembled sets. Begin with either hole located furthest back, at the corners of the optical breadboard; see Figure 26 and 27 below. Starting with a back corner makes it easier to orient the remaining sides of the chamber base. Insert a $\frac{1}{4}$ "-20 x 0.5" bolt along with a $\frac{1}{4}$ " washer into the L-shaped slot hole found on each of the four assembled sets. Screw into the hole, but do NOT tighten yet; see Figure 27 for an example. Work clockwise or counterclockwise doing the same with the remaining three sets. Once all four corners of the chamber base have been situated, move on to tighten the screws. However, also tighten the screws one at a time in clockwise or counterclockwise order while making sure each male/female joint between the eight parts is as close-knit and tight as possible. The setup should now resemble Figure 28.

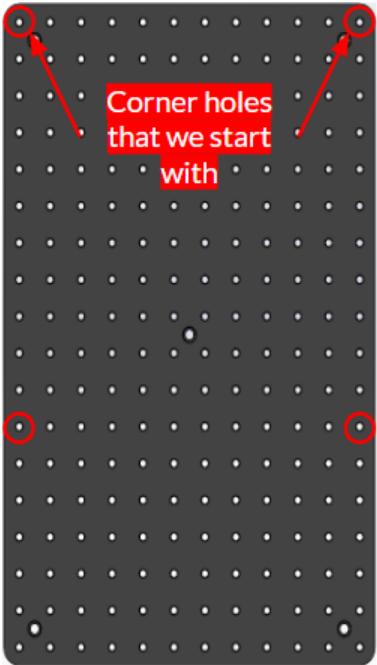


Figure 26



Figure 27

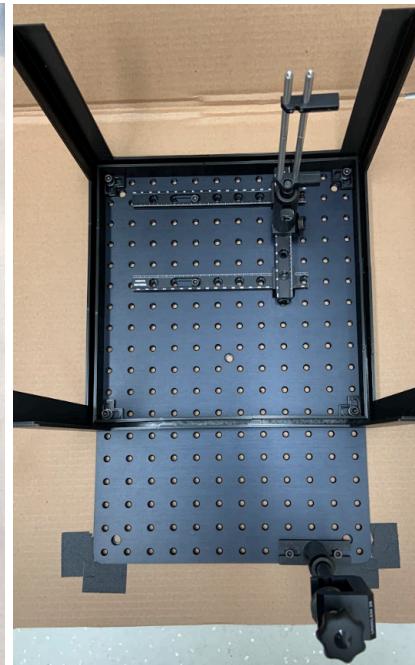


Figure 28

Front Panel With Opening Adapter Assembly

12)

Materials Needed

- (TC000-13) White Styrofoam Board w/ adhesive side, 12" x 16", thick x4
- (TC2000-106) Scissors
- (TC000-15) Black Cardstock
- (TC2000-109) Gaffer Tape

Cut the large sheets of cardstock to size and stick them onto one side of the white styrofoam board; this side will be facing out. It is okay if more than one sheet of card stock is needed to achieve this. If you cannot find sticky white foam boards, you can also use normal white foam boards with double-sided tape. Then, line all the edges with a piece of Gaffer tape to prevent the sides from fraying. Do this to all four boards. Only one of them will be used for Step 13, so set the other three aside for Step 17.

13)

Materials Needed

- One of the assembled black and white boards from Step 12
- (TC2000-108) Box cutter
- (TC2000-105) Ruler
- (TC2000-107) Pencil

Use the pencil and the ruler to sketch the box using the dimensions shown in Figure 29 below. Use the box cutter to cut the line you drew. You should now have two pieces of styrofoam; one larger piece with dimensions of 12" x 9" and a smaller piece with dimensions 12" x 7".

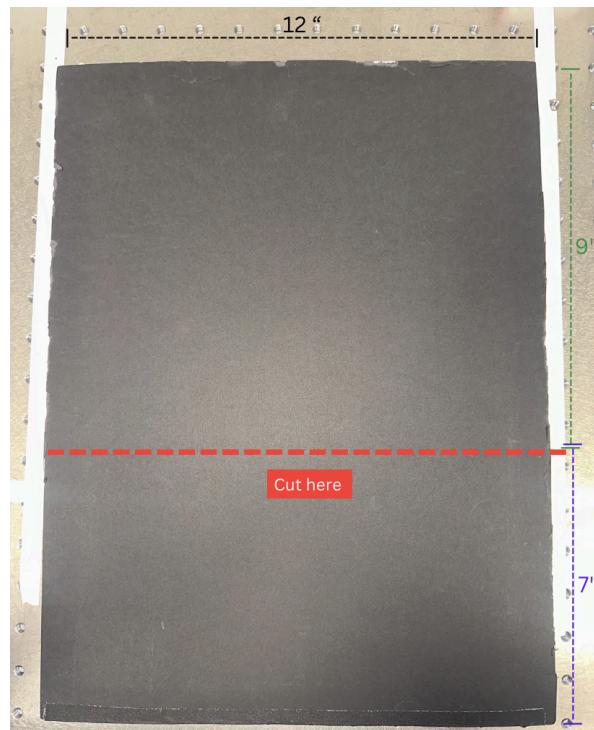


Figure 29

14)

Materials Needed

- Assembled board from Step 13
- (TC000-16) Chamber Opening Adapter
 - Left side of the chamber opening adapter (COA) x2
 - Right side of the chamber opening adapter (COA) x2
- (TC000-31) 29cm Brush Strip
- (TC000-32) 28cm Brush Strip

Insert the COAs one at a time. Make sure the lips on the adapters slide onto the lips of the rectangular opening, see Figures 30 - 32 below for what this looks like. The protruding side of all the COA components must be on the white side of the board.



Figure 30

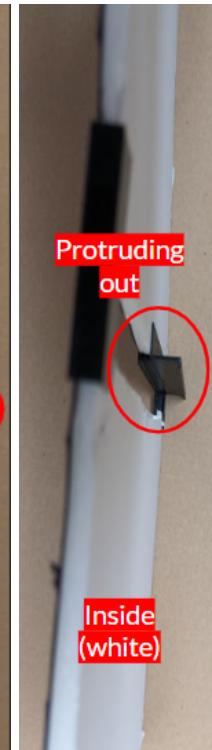


Figure 31



Figure 32

15)

This step is a continuation of Step 14. Insert the remaining three COA components, ensuring that the union of the left and right sides is tight. Figure 33 below shows how the left and right should fit together in the middle. Note that if the left and right parts do not sit flush with each other (i.e., there are gaps greater than 1 mm), the parts are not aligned correctly. Remember that the protruding side of the COAs is on the white side of the board. Figures 34 - 36 are snapshots of the assembly progress for the remaining three COA components. Figure 37 is the finished product.

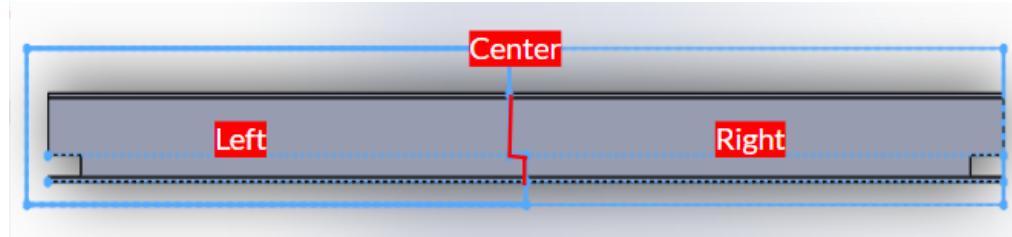


Figure 33



Figure 34



Figure 35



Figure 36



Figure 37

16)

Apply the brush strips on opposing sides, staggered from each other. Make sure that the corners are covered up to prevent light from coming into the chamber. The 28cm strip should be placed as shown in Figure 38. The 29cm strip should be placed like in Figure 39. When putting the wall onto the PTC, the setup should look like Figure 40.



Figure 38

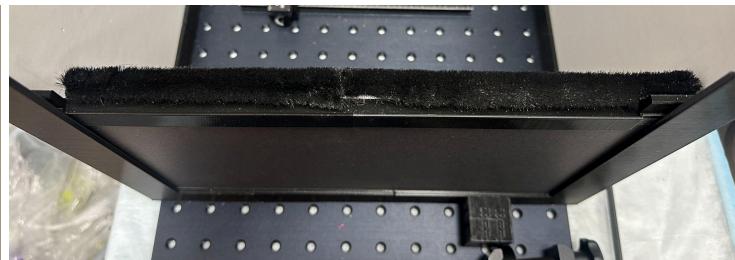


Figure 39



Figure 40

Chamber Walls Assembly

17)

Materials Needed

- Assembly of front panel from Step 15
- Three remaining assembled black and white boards from Step 12

Slide the walls into the grooves found in the chamber base using the front panel made from the last section as the front wall and the three unmodified black and white styrofoam panels for the remaining three sides; make sure the white side is on the inside for each panel. Make sure to follow the unique edge-to-edge intersection shown in the figures below. Note that there are two viable conformations. Figures 41 and 42 below only show one of the two conformations.

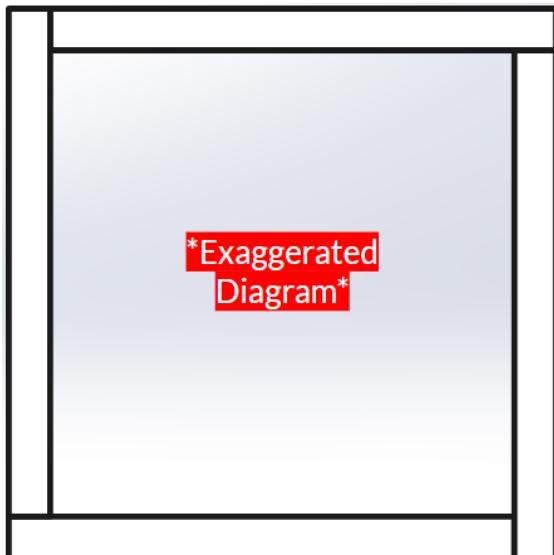


Figure 41

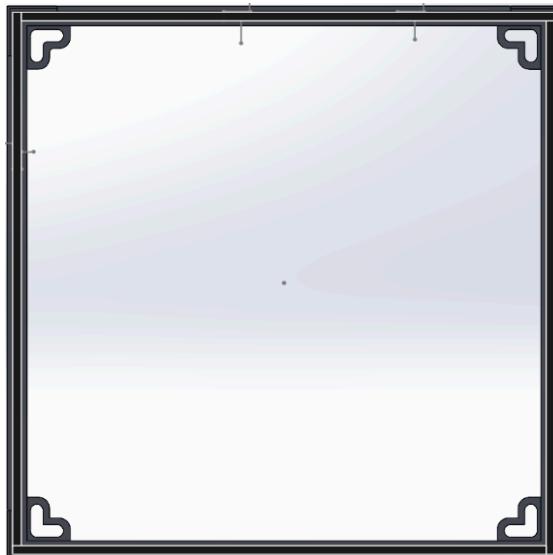


Figure 42

Top Chamber Frame and LED Array Assembly

18)

Materials Needed

- (TC000-14) White Styrofoam Board w/ adhesive side, 12" x 12"
- (TC000-15) Black Cardstock
- (TC2000-106) Scissors
- (TC2000-109) Gaffer Tape

Similar to what you did in Step 12, cut the large sheets of cardstock to size and stick them onto one side of the white styrofoam board; this side will be facing out. It is okay if more than one sheet of card stock is needed to achieve this. If you cannot find white styrofoam boards with one adhesive side, you can also use normal white foam boards with double-sided tape. Then, line all the edges with a piece of Gaffer tape to prevent the sides from fraying.

19)

Materials Needed

- (TC000-26) Ceiling Frames x4

Similar to how you fitted the panels into the grooves of the chamber base, you will fit the panels into the grooves of the chamber top right on top of the walls we put in. If all the panels are in decent structural shape, this should be easy. The four identical components should fit like what is shown in Figure 43 below.

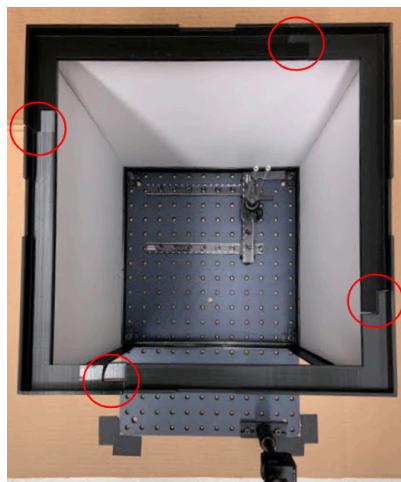


Figure 43

20)

Materials Needed

- Assembled black and white board from Step 18
- (TC000-24) Tape
- (TC000-12) LED Array x2
- (TC000-10) Adhesive metal plates x4
- (TC2000-107) Pencil

Flip to the white side of the board, and center two horizontal LED light bars, side-by-side on their long edge, roughly 1" from the bottom of the board; please see Figure 44 below. Make sure to center the LED portion of the light bars and not the light bars themselves. Take a pencil and roughly trace the entire light bars so you can use the outline to locate and adhere to the four

metal plates. These metal plates will be used to attach the light bars. In place of the metal plates, you can also use tape or velcro.

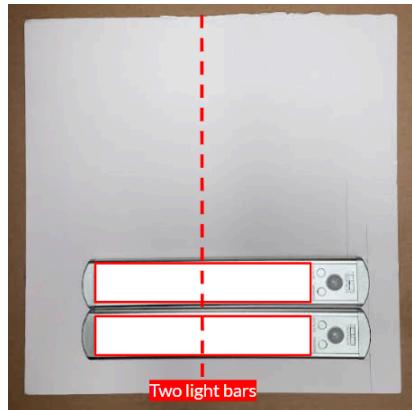


Figure 44

21)

Materials Needed

- *Assembled board from Step 19*
- (TC000-24) Tape

This step requires the board from the last step and some tape. Please refer to Figures 45 and 46 below. You will simply adhere two pieces of tape to each other using their sticky sides. However, you will stick both tapes onto the boards as well such that the result is a “tab” that we can hold onto to more easily lift the lid of the PTC. The resulting tab should no longer be sticky. Place the lid onto the chamber with the light bars facing you. The top panel should be easily liftable. Congratulations! You are done!



Figure 45

Figure 46

Glossary

Counterbore - a cylindrical cut-out right above the hole that a bolt is inserted into so that the cylindrical cap of the bolt is hidden along with the body when the bolt is fully inserted.

Tapping - carving and removing material from a hole to form threads that make bolt insertion easier/possible. This is usually conducted using a specialized tool.

Set screw - a “capless” screw that is typically used without a nut.