

UCLA GAME LAB
ARCADE
BACKPACK
FABRICATION GUIDE



Arcade Backpack Overview

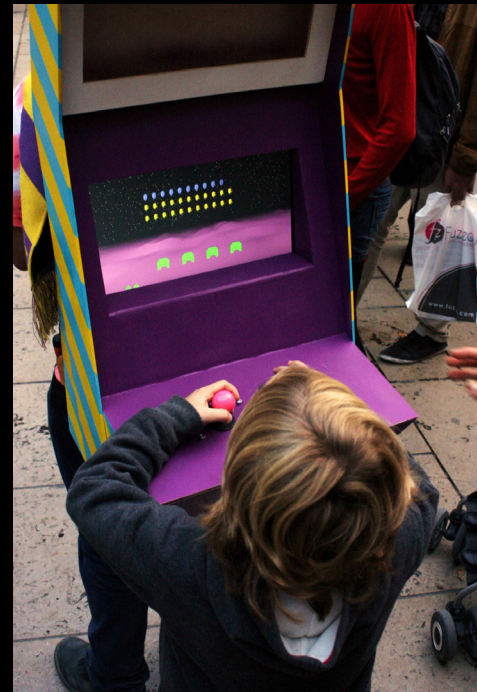
The Arcade Backpack was created to infiltrate public space. Ironically, the backpack's debut at the 2nd Annual UCLA Game Art Festival was so successful in infiltrating our own event that it stole the show and has become the most popular above ground Game Lab project.

The cabinet frame is constructed of lasercut plywood and assembled to house a laptop, arcade style controls, and an LED marquee. The entire cabinet is attached onto a military grade frame and can be adjusted to fit comfortably on any unsuspecting Game Lab resident. To see it in action, [click here](#).



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I. About this Guide

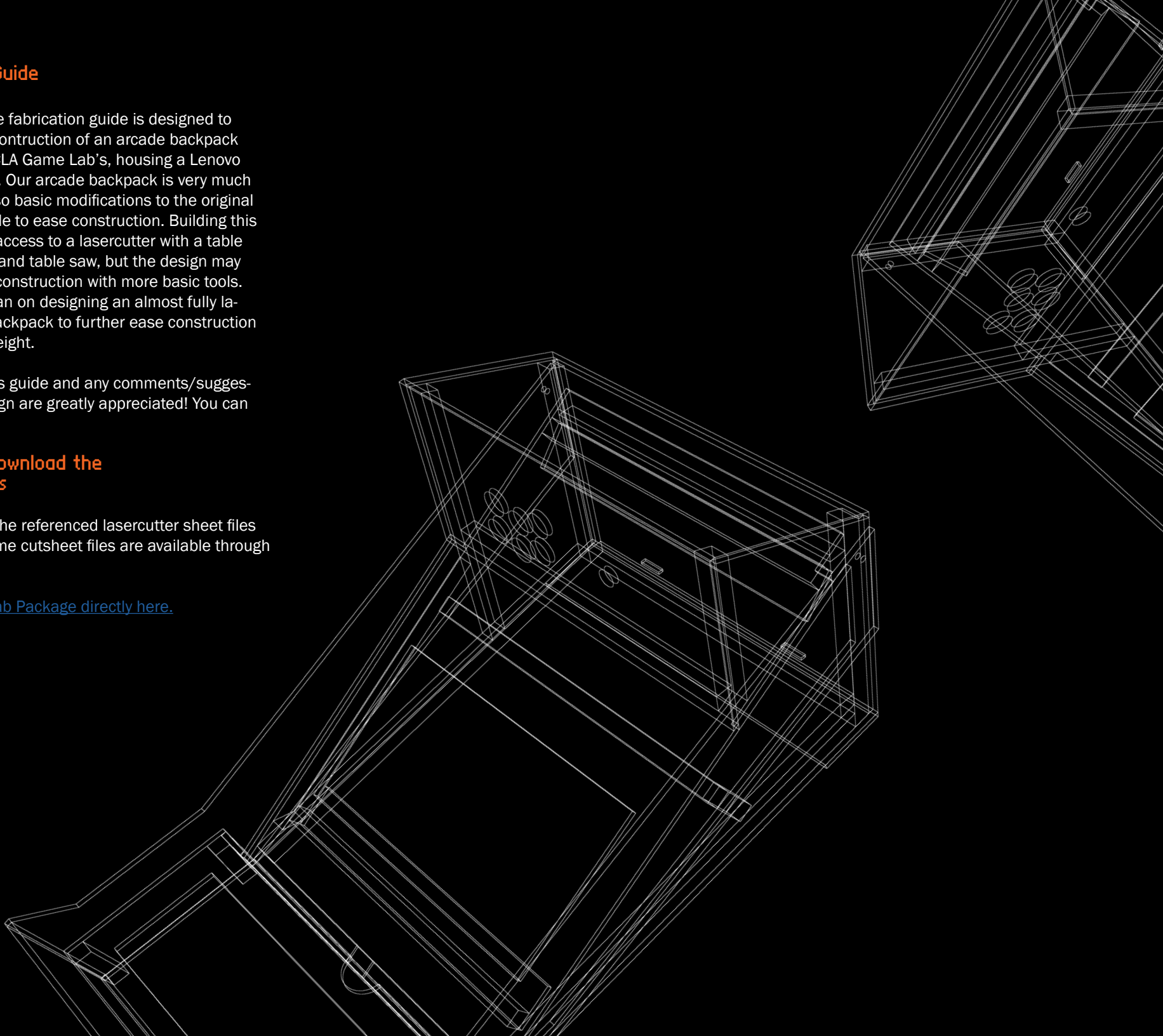
This open-source fabrication guide is designed to streamline the construction of an arcade backpack similar to the UCLA Game Lab's, housing a Lenovo ThinkPad W520. Our arcade backpack is very much an alpha build, so basic modifications to the original model were made to ease construction. Building this model requires access to a lasercutter with a table size of 32"x18" and table saw, but the design may be modified for construction with more basic tools. Ultimately we plan on designing an almost fully lasercut arcade backpack to further ease construction and shave off weight.

Feedback on this guide and any comments/suggestions to the design are greatly appreciated! You can contact us [here](#).

II. Where to Download the Template Files

This guide with the referenced lasercutter sheet files and to-scale frame cutsheet files are available through Github [here](#).

[Download the Fab Package directly here.](#)



III. Materials List

Wood + Hardware + Finishing

- 4 32" x 18" x 1/4" plywood sheets
- ~20' x 3/4" x 3/4" lumber/square dowel
- Wood glue
- Latex primer
- Your preferred colors of latex paint
- Polyurethane clearcoat
- ~80 3/4" wood screws
- ~4 1 1/2" wood screws
- 2 10-24 x 1-3/4 hanger bolt
- 2 10-24 wing nuts

Tools

- Lasercutter (highly recommend- ed) **OR** track saw **OR** circular saw with angle guide
- Table saw
- Miter saw
- Drill with bits, counter sink, and drivers (including 10-24 hanger bolt driver)
- Flat head screwdriver
- Sandpaper of various grades
- Chisel
- Soldering iron
- Wire stripper
- Wire cutter
- Crimping tool
- Hot glue gun
- C-clamps
- Measuring Tape

Computer + Control Panel Electronics

- Laptop that can open up flat, isn't too heavy, and has a long battery life
**We're using the [Lenovo ThinkPad W520](#)*
- 6 arcade-style momentary push buttons with microswitches **Our control panel template is designed for buttons with a 1 1/8" mounting hole such as [this one](#). Different button sizes may require a different layout *For more info on button/joystick layout [see here](#).*
- 18 female quick disconnects such as [these](#) for the button terminals
- Wire for the buttons and joystick. The quick disconnects above take 16-14 AWG
- Terminal strip
- Arcade joystick such as [this one](#).
**One of the highest quality and most popular joysticks is the Sanwa JLF, but it's pricier. Joysticks by Seimitsu are also a good choice. If you're planning on building a two player control panel, purchase joysticks that are as compact as possible because the panel is a bit narrow.*
- Superglue for mounting the joystick to the Control Panel **OR** flat head machine screws and bolts that fit the joystick's mounting plate plus a lasercut opaque plexiglass panel to cover the top of the Control Panel
- USB microcontroller ** We're using the [Teensy 2.0](#) because it's small and inexpensive. however it requires the extra step of loading software onto the Teensy that converts it into a USB keyboard. Another option is to use a PCB designed specifically for a custom controller, [such as the I-PAC](#), which includes built in terminal strips and pre-loaded software.*
- USB cable to connect the microcontroller to the laptop ** The Teensy 2.0 takes a USB Mini-B plug*
- Screw-in wire routing clip to keep the USB cable from pulling out of the controller
- Adhesive backed felt tape or pads to protect the laptop from the Computer Support Panels
- Bluetooth keyboard with touchpad to load games while the backpack is assembled (optional) ** Alternatively, a USB extension cable can be left plugged into the laptop with the free end secured to the exterior of the arcade backpack*

Backpack

- MOLLE II frame with straps
- 2 1" wide by ~10" long nylon webbing straps with sewn on stap adjustors or cam buckles
- 3 1" wide by ~18" long nylon webbing straps with sewn on stap adjustors or cam buckles

Misc

- Solder
- Hot glue

Marquee

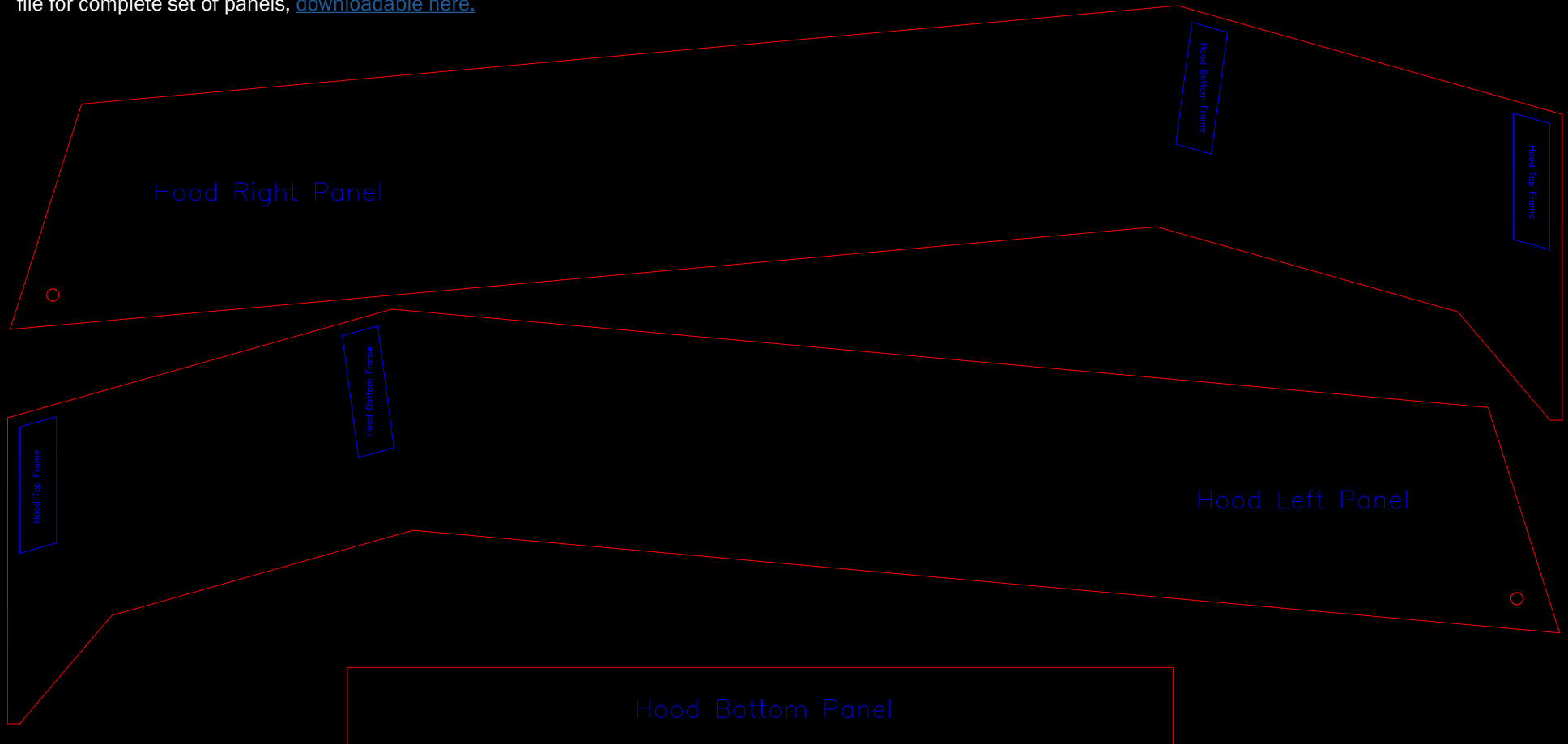
- Adhesive backed analog type RGB LED strip for backlight ~1m long
- Rechargeable 12V battery or 8 x AA batteries and holder to power the LEDs
** We used a 12V drill battery then replaced it with two RC car batteries, connected in series, to save weight*
- Tabloid size transparency film and printer.
** Alternatively you can use professional backlit sign printing services*
- 14" x 7" x 1/8" Frosted plexiglass
- 28" x 1/2" x 1/16" Double sided foam tape
- Screw-in wire routing clip and small machine screws + nuts

IV. Panel + Frame Preparation

Prepare panels

The easiest way to cut out the plywood panels is with a lasercutter. The attached Illustrator cutsheet is for a laser cutter that can fit 32" x 18" sheets of material. The red lines represent cuts, and the blue lines represent etched lines. The etched lines on the Hood Sides and Screen Panel are for aligning glued frame pieces. The dashed line on the Screen Panel is for aligning the Computer Support Bottom Frame which may be screwed on.

Locate the [panel_cutsheet.ai](#) in the Fab Package zip file for complete set of panels, [downloadable here](#).



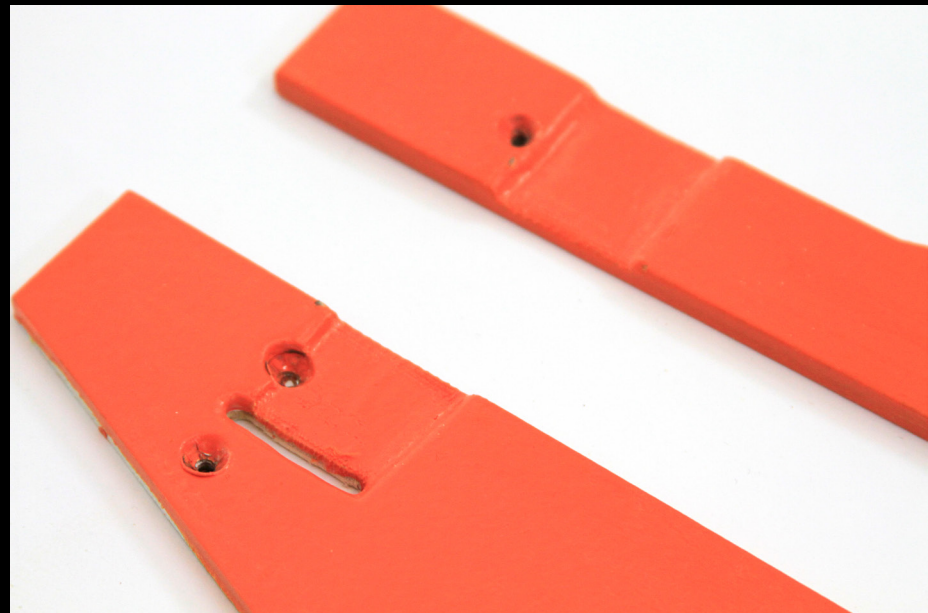
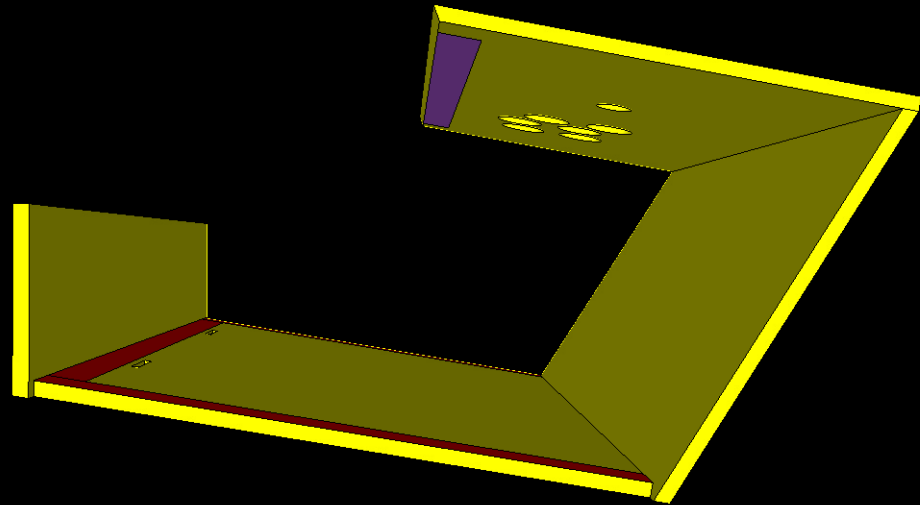
Mitering the panels

IMPORTANT: The dimensions listed on the cutsheet are of the panels' longest measurements, so mitering should not affect these measurements.

Here's the breakdown of how the panels are mitered. Positive angles represent a cut with the outer (world facing) surface of the piece facing up on the table, negative angles represent the inner surface of the piece facing up on the table. Check out the green panel side views on the panel cutsheet if this gets confusing.

TIP: The etched names of the panels are always on the inner surface of the piece.

- a. Base Front Panel - the bottom is mitered at a -23° angle, the top at 23° , making it parallel to the first cut.
 - b. Control Panel - the back is mitered at 30°
 - c. Base Bottom - the back is mitered at -10°
 - d. Base Back - the bottom is mitered at -10°
 - e. Marquee Panel - the bottom is mitered at -8° , the top at 16°
 - f. Hood Back - the top is mitered at -16°
1. Chisel out shallow slots for the nylon webbing on the **OUTSIDES** of both of the Base Side Panels. These areas are etched on the insides of the panels with diagonal lines.



Prepare Frame Pieces

Use the frame cutsheet for reference. Starting with the longest frame piece, measure and mark it's length on the 3/4" x 3/4" lumber. Then, using the miter saw, cut the piece to length with the required miter angle. You may be able to measure and cut the next piece, maintaining the mitered end you just created, because some pieces share miter angle ends.

IMPORTANT: The dimensions listed on the cutsheet are of the frame pieces' total length, so mitering the ends will not affect these lengths.

Here's a list of the miter angles required. Negative angles represent a cut parallel to the first cut.

1. Chisel out a webbing slot in the center of the Screen Top Frame on the freshly mitered front face, 1 1/8" wide and 1/8" deep

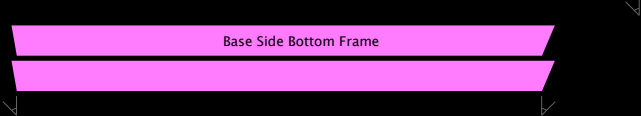
Hood Left/Right Top Frame - the front is 16°, the back is -16°



Hood Left/Right Bottom Frame - the front is 8°, the back is -8°



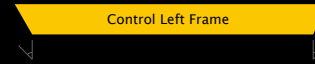
Base Side Bottom Frame - the back is 10°, the front is 23°



Base Back Bottom Frame - the long-side back is 10°



Control Left Frame - the back is 30°, the front is 23°



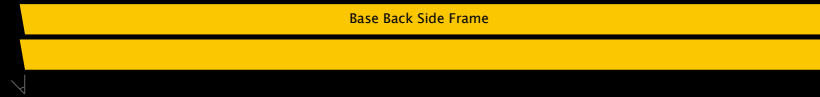
Control Right Frame - the back is 10°, the front is 23°



Control Back Frame - the long-side back is 30°



Base Sides Back Frame - the bottom is 10°



Screen Right Frame - the bottom is 30°, the top is 45°



Screen Bottom Frame - the long-side back is cut at a 30° angle



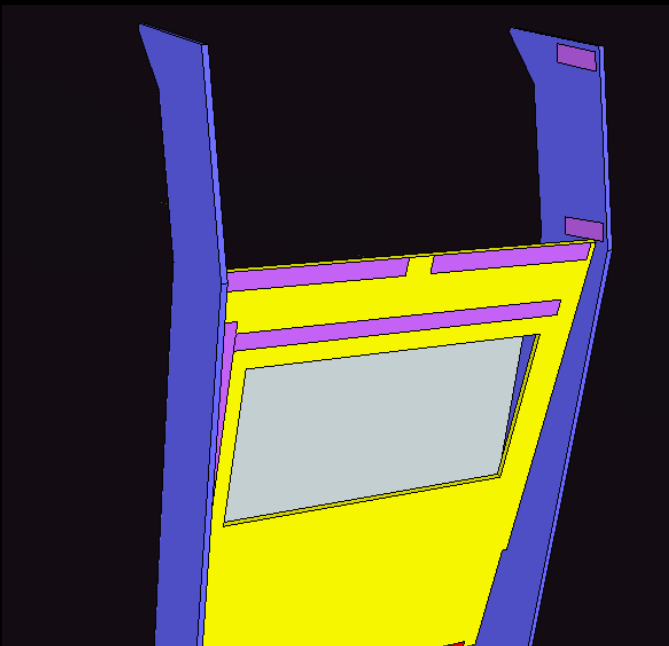
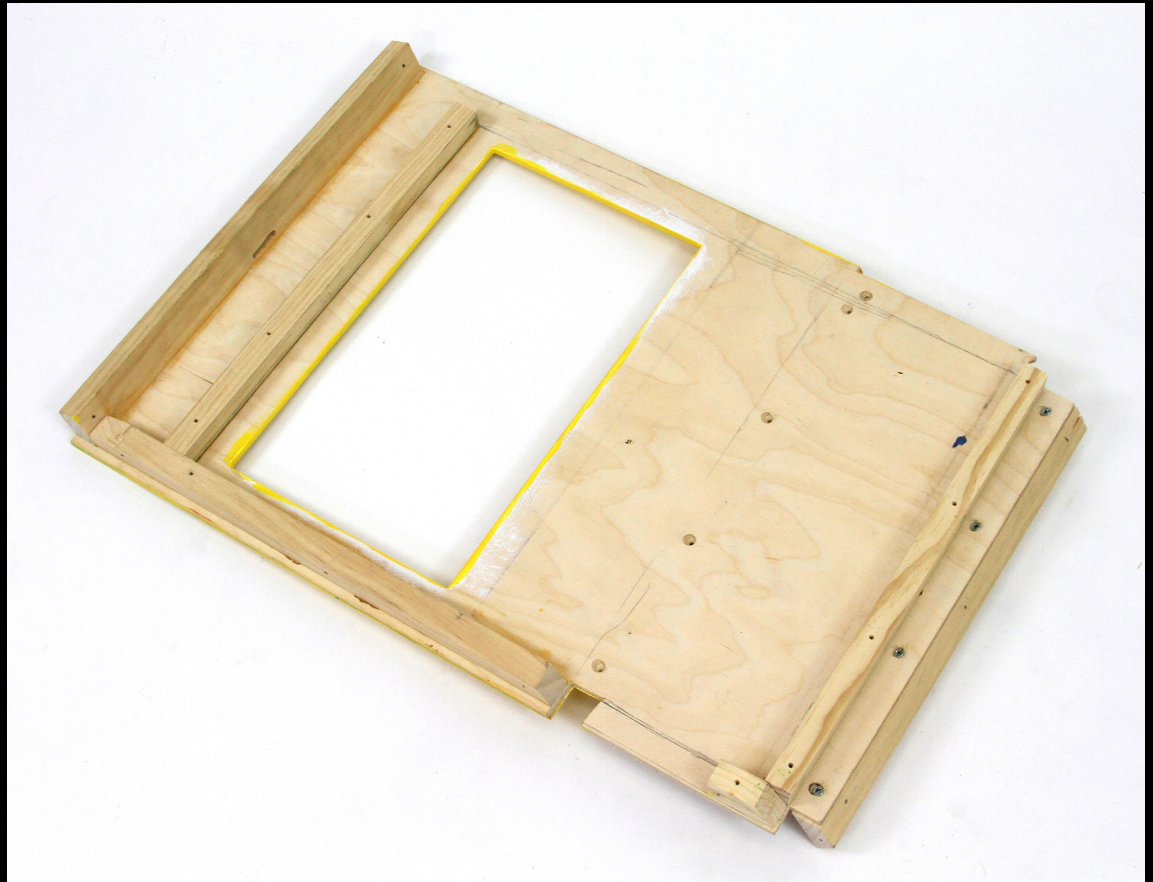
Screen Top Frame - the long-side front is 20°



Mount Frame Pieces to Individual Panels

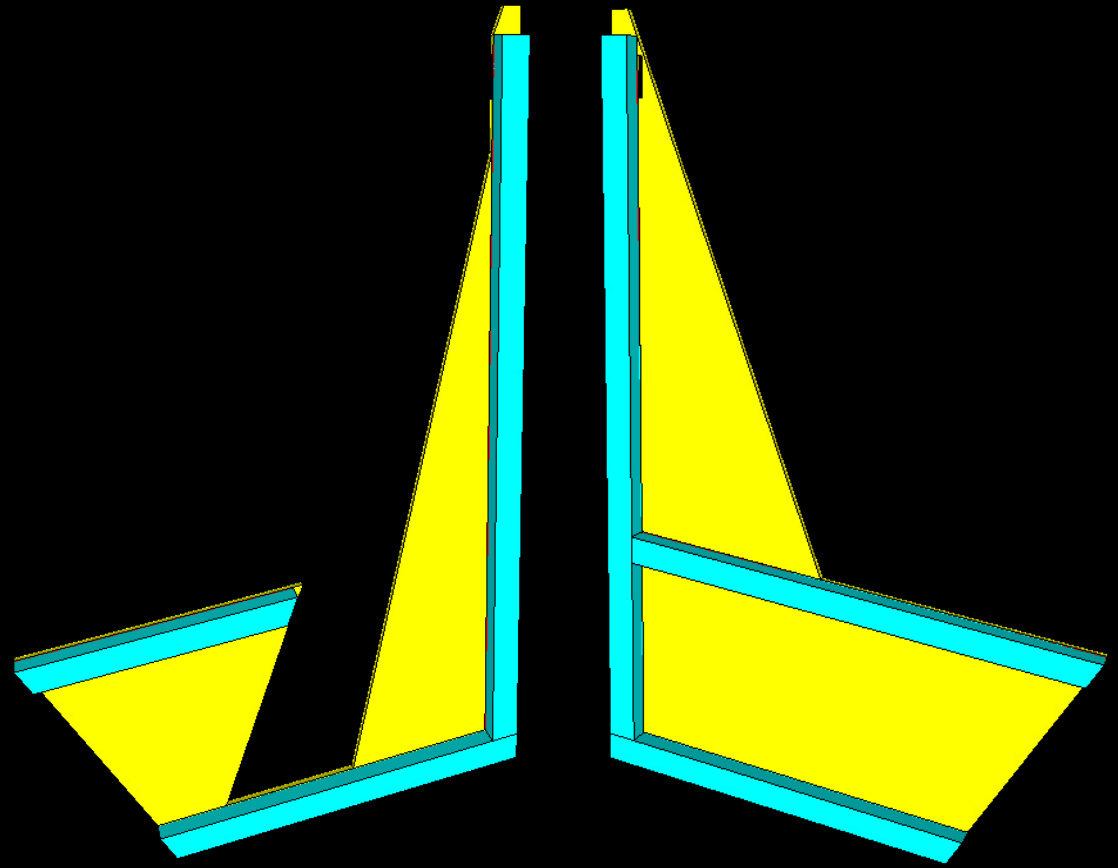
On the Sketchup model, the lavender sides of the frame pieces represent the sides that get glued to the lavender spaces on panels. These spaces are etched onto the panels with solid lines. Following the etched guides, proceed to glue using wood glue and clamps:

- a. Control Back Frame (with 30° miter at back and narrow side facing down) onto the Control Panel
- b. Screen Right Frame (with long side touching panel and 45° miter at top) onto the Screen Panel
- c. Screen Top Frame (with 20° miter touching panel and narrow side facing the top) onto the Screen Panel
- d. Hood Bottom Frame and Hood Top Frame onto the inside of Hood Left Panel
- e. Hood Bottom Frame and Hood Top Frame onto the inside of Hood Right Panel



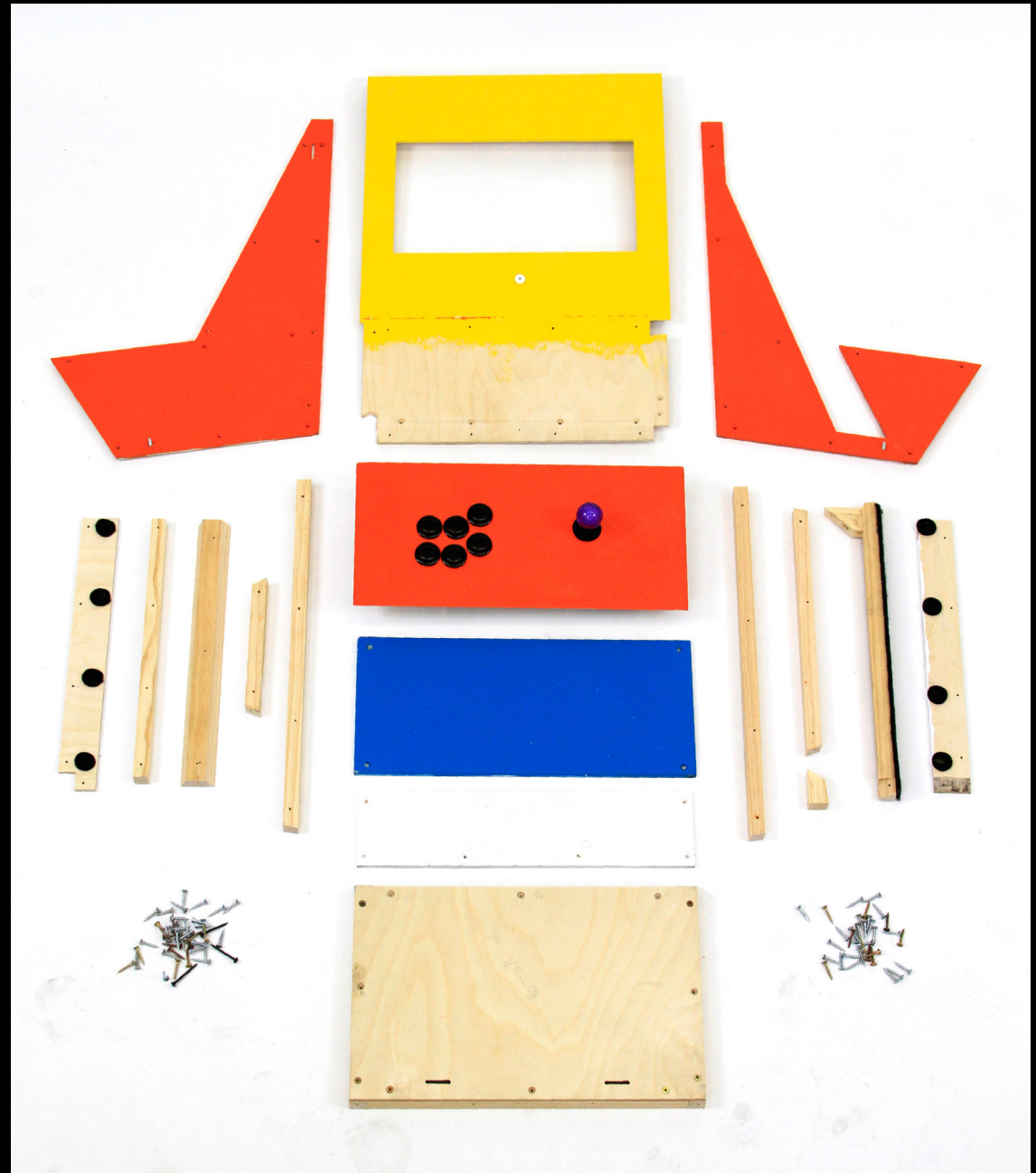
On the Sketchup model, the red spaces on panels represent the sides that get screwed onto the red sides of frame pieces. These spaces are etched onto the panels with dashed lines. Pieces to be screwed together should be clamped and have pilot holes drilled and countersunk from the panel side.

- a. Base Side Bottom Frame pieces (aligned to back edge with short side touching panel and 10° miter at back) to the inside of the Base Bottom Panel
- b. Base Back Bottom Frame (aligned to back edge with narrow side touching panel and 10° miter at back) to the inside of the Base Bottom Panel
- c. Control Left Frame (long side aligned with Control Panel edge and 23° miter aligned to front edge) to Base Left Panel
- d. Base Back Side Frame (aligned to dashed lines) to Base Left Panel
- e. Control Right Frame (long side aligned with Control Panel edge and 23° miter aligned to front edge) to Base Right Panel
- f. Base Back Side Frame (aligned to dashed lines) to Base Right Panel
- g. Computer Support Bottom Frame (mitered side facing away from panel and narrow side facing bottom) to Screen Panel
- h. Screen Bottom Frame (mitered side touching panel and narrow side facing top) to Screen Panel



Paint and Clearcoat the Panels

1. Sand any sharp edges or rough countersunk holes on the panels and wipe off any dust/grime.
2. Prime the outside faces and edges of the panels. The inside faces of the Hood Right Panel and Hood Left Panel should be primed as well. Also, to improve light reflection, prime the inside face of the Hood Back Panel.
3. Paint the outside faces and edges of the panels with a wacky color scheme, or groovy original artwork. Both sides of the Hood Right Panel and Hood Left Panel should be painted. Our arcade backpack required 2 to 3 coats of latex paint for full coverage.
4. Protect the outside faces and edges of the panels with multiple layers of a hard-drying polyurethane clear coat.



V. Arcade Controller Panel Construction

Install the joystick

1. Remove the top ball from the joystick if it's screwed on, and remove the dustwasher disk. There's usually a slot in the bottom of the joystick shaft for a flat head screwdriver to aid in removal of the top ball.

2. To mount the joystick to the control panel, we just slathered the top of the joystick mounting plate with superglue, raised the control panel off of a table with blocks, and stuck the joystick onto the bottom of the control panel, ensuring that it was square to the panel.

*** OR** If you want the joystick to be removable, you can drill holes in the Control Panel that align with the mounting plate and counter sink the holes on the top of the Control Panel.

Drop bolts from the top and place washers and nuts underneath the panel so that the bolts sit flush with the top of the Control Panel.

Laser cut an opaque, 1/8" thick plexiglass topper for the control panel to hide the bolt heads, using the same cutsheet used to cut the Control Panel. The buttons, once installed, will hold the plexiglass in place.

Install the arcade buttons

1. Remove the microswitches from the buttons, if they're installed.

2. Unscrew the nut from the button.

3. Insert the button into the top of the Control Panel and tighten it down from the bottom with the nut.

4. Reinstall the microswitches.



Wire it up!

1. Cut 6 short lengths of wire (~6"), and strip the ends. Crimp on the first quick disconnect to one wire and on the other end, splice it with a second wire into another quick disconnect. Continue this splicing process creating a daisy chain of quick disconnects until you have six quick disconnects and a free wire end. This will distribute a ground to your six buttons. Plug the six quick disconnects into the "common" leads on the button microswitches (generally the lead on the bottom of the switch).

2. Cut 6 slightly longer lengths of wire, strip the ends, and crimp a single quick disconnect onto each wire. These will connect the switches' signal leads to the microcontroller's individual control inputs. Each microswitch has two signal leads, a "NO" lead (normally open) and a "NC" lead (normally closed). Plug the quick disconnects into the NO leads (generally the lead closer to the bottom of the switch).

3. Some joysticks come with a preinstalled wiring harness, others have exposed microswitches, and others just have bare terminals sticking out of a PCB. If the switches are exposed, repeat the button wiring steps for the four switches. Our joystick had bare terminals (a single ground and four signal terminals) that we soldered wires to.

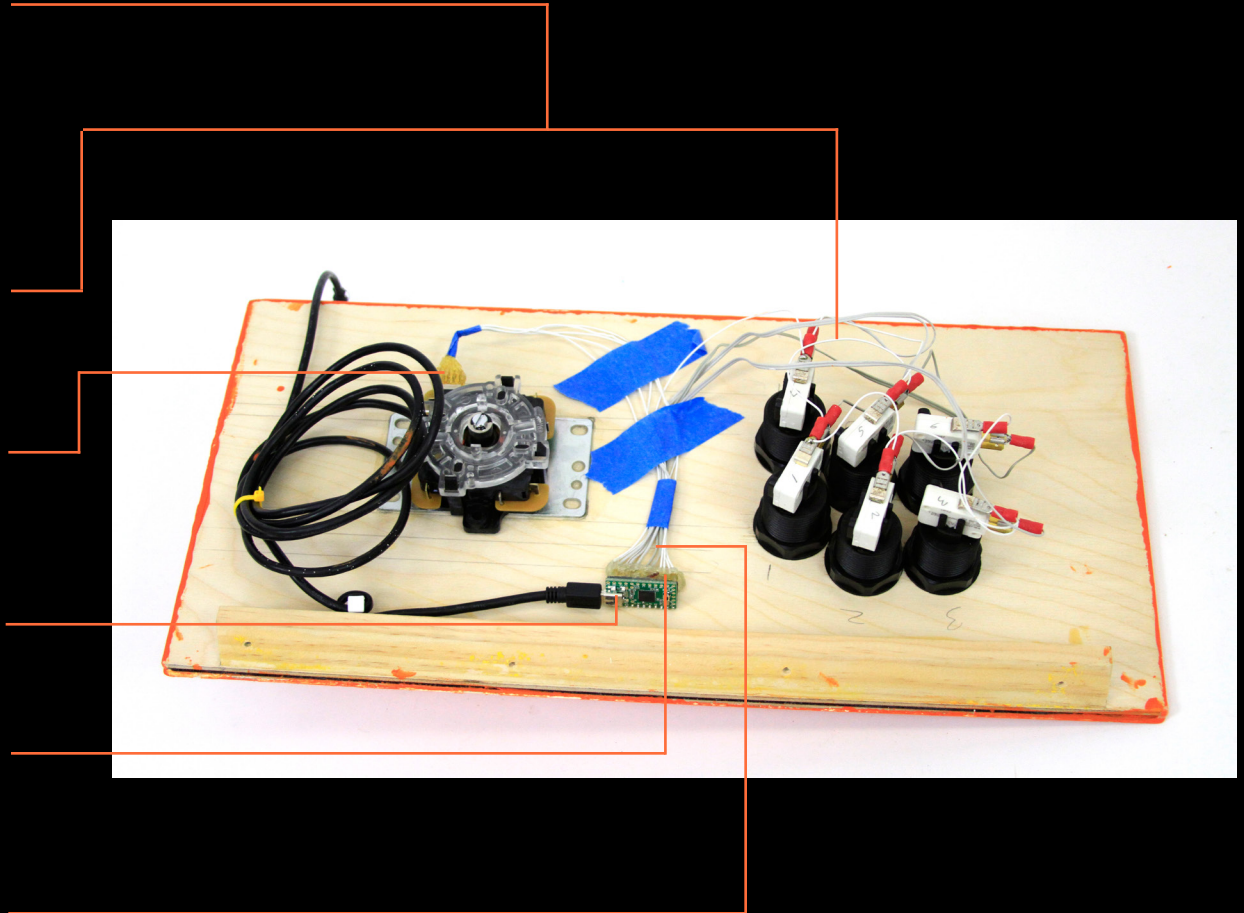
4. Mount a terminal strip to a central location on the Control Panel to organize the wires and make it easier to add buttons or switch out the microcontroller. We skipped this step out of laziness.

5. Insert your 6 button and 4 joystick signal wires into one side of the terminal strip. Twist together the button ground and joystick ground wires and insert next to the signal wires.

6. Cut and strip 11 short wires. Connect each one to the other side of the terminal strip and solder them to the microcontroller. The ground wire will be connected to ground on the controller, and the rest to individual control inputs. The order of inputs should be logical. Our layout and Teensy sketch uses the top three buttons in inputs 0-2, the bottom three buttons in inputs 3-5, and the joystick switches in inputs 7-10.

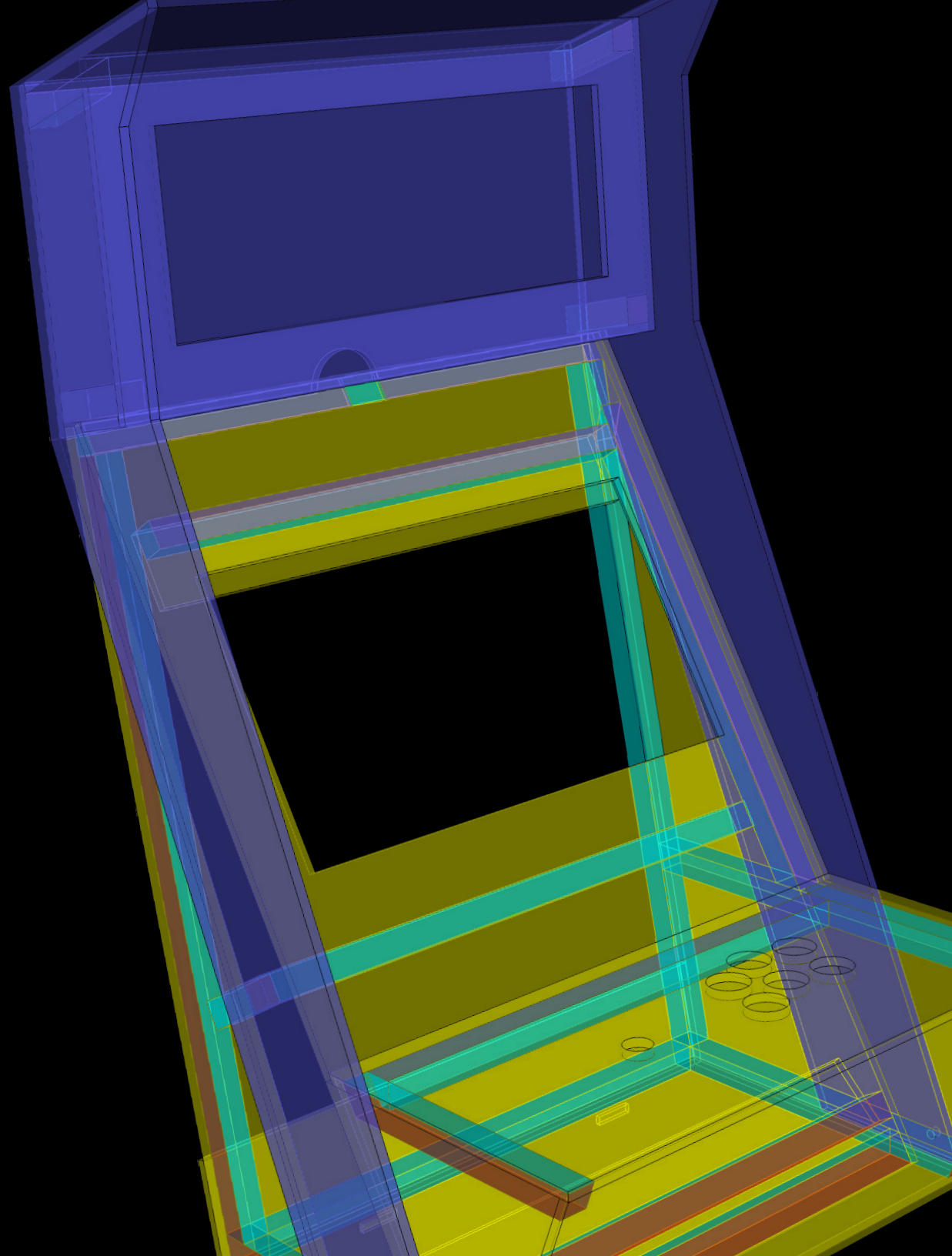
7. We covered all soldered connections in hot glue for strength.

**A note on pullup/pulldown resistors: The Teensy and Arduinos with Atmega chips have internal pullup resistors that can be accessed through code, so wiring resistors between the buttons and power isn't necessary.*



Finishing touches + software

1. Mount the microcontroller to an open area on the bottom of the Control Panel. Hot glue is relatively secure for this. Insert the mini USB cable into the microcontroller.
2. Secure the USB cable to the Control Back Frame using the screw-in cable clip
3. If you're using a microcontroller without preloaded software, such as a Teensy or Arduino, you'll have to program the board to appear as a native Mouse and/or Keyboard. For more information on using an Arduino (Leonardo, Micro, or Due models only) as a keyboard check out [the Arduino reference](#). For a Teensy native joystick [see here](#). To load our Teensy sketch [standard_layout.pde](#), first install the Teensyduino application and select a Joystick type from the Tools -> USB Type menu. Open the sketch and upload it to the board. **REMEMBER:** This sketch is written for buttons on inputs 0-5 and a joystick on inputs 7-10. Now your Teensy will be recognized as a joystick by the laptop.
4. Many games are controlled by keyboards rather than joysticks, so another useful software tool to have is a keymapper to convert joystick button presses to keypresses. We're currently using [joy2key](#) on the laptop.



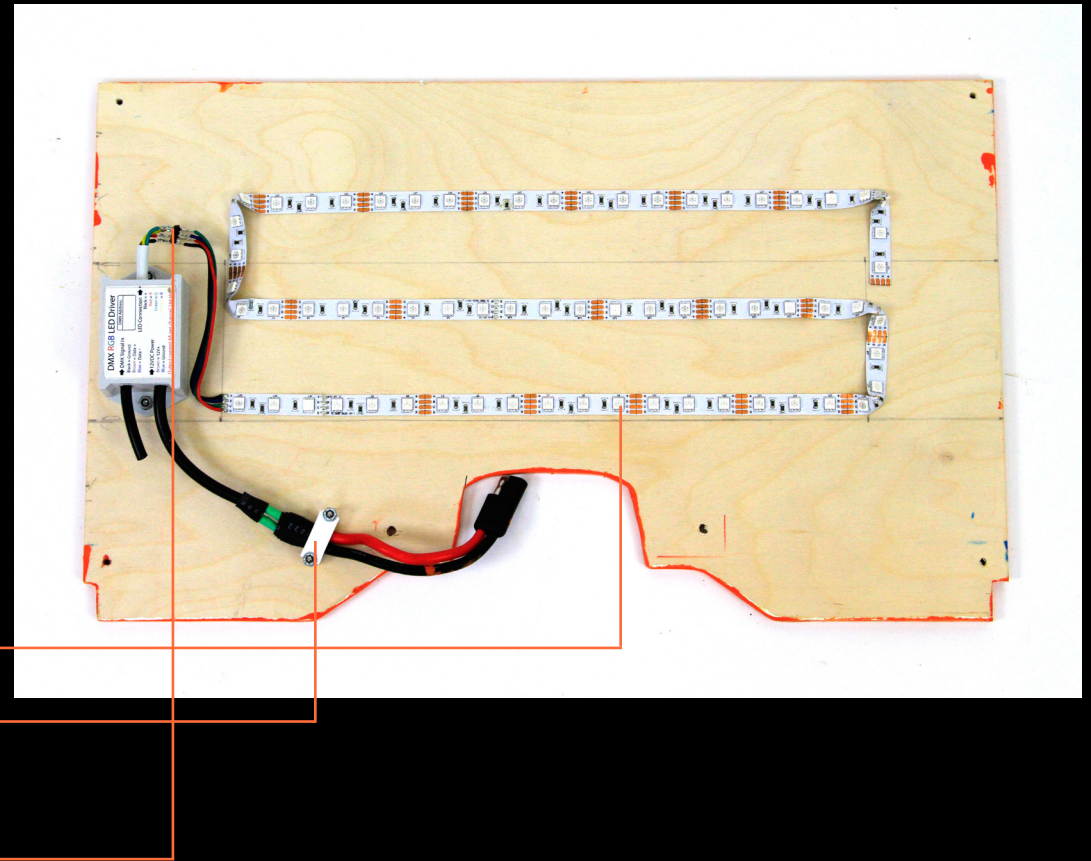
VI. LED Marquee Assembly

Wiring the Marquee LED strip

1. There are a few options for controlling the LED strip. We're using a basic LED controller PCB that automatically fades between different colors. Another option is to use a controller with an IR Remote and multiple lighting pattern modes. The best solution would be to integrate the LED strip control into the Control Panel microcontroller, allowing you to program custom lighting sequences and interactive patterns based on button presses. [Here's a great tutorial on controlling an analog LED strip with an Arduino.](#) Regardless of your controller choice, solder a 4 wire cable and connector onto the end of your LED strip to allow separation of the Hood and Base chunks of the backpack. 4-pin JST SM type connectors are commonly used with LED strips.
2. Remove the paper from the adhesive backing of the LED strip and stick it to the inside face of the Hood Back Panel, snaking it back and forth to cover a large area of the panel.
3. Secure the LED strip end of the 4-pin connector cable to the inside of the Hood Back Panel by bolting it under a cable clip.
4. Solder the other end of the 4-pin connector to your controller/battery system, and mount the battery pack to the inside bottom of the Base using double sided adhesive foam tape.

Assemble the Marquee

1. Stick two 14" strips of foam tape to the top/bottom long sides of the piece of frosted plexiglass. Center the plexiglass over the opening on the back of the Marquee Panel and stick it down. This leaves a 1/2" tall slot at the top and bottom of the marquee opening which holds the marquee graphic in place.
2. Print out your marquee graphic at 14"x6" on an appropriately sized printer transparency sheet (tabloid sized is commonly available and large enough). Print with a high ink density to get bright colors and opaque blacks when backlit.
3. Cut out the marquee graphic and flex it slightly to slip into the hole in the front of the Marquee panel. The graphic is inserted from the front of the panel so that when the Hood is assembled, the graphic can be easily switched out.



VII. Final Assembly

On the Sketchup model, the red spaces on panels represent the sides that get screwed onto the red sides of frame pieces. These spaces are etched onto the panels with dashed lines. Pieces to be screwed together should be clamped and have pilot holes drilled and countersunk from the panel side.

Assemble the Hood. Proceed to screw together:

- a. Hood Back Panel to the backs of the 4 frame pieces glued to the Hood Right/Hood Left Panels with the half circle cutout on the bottom
- b. Marquee Panel to the fronts of the 4 frame pieces glued to the Hood Left/Right Panels
- c. Hood Top Panel to the tops of the 2 Hood Left/Right Top Frame pieces glued to the Hood Left/Right Panels, butting it up against the Hood Back Panel
- d. Hood Bottom Panel to the bottoms of the 2 Hood Left/Right Bottom Frame pieces glued to the Hood Left/Right Panels, butting it up against the Marquee Panel



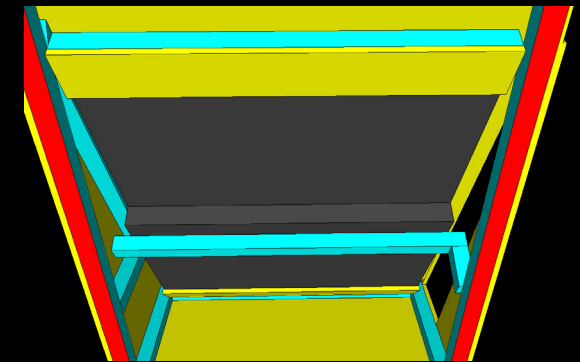
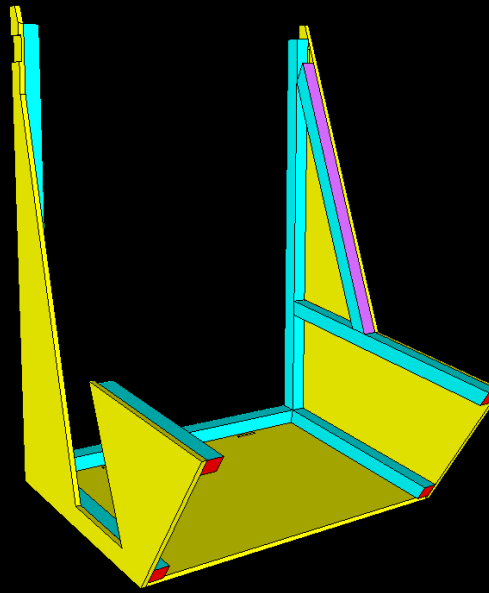
Assemble the computer supports

1. Stick a strip of adhesive backed felt tape to half of the Computer Support Top/Bottom Panels
2. Screw the Computer Support Top/Bottom Panels into the Computer Support Top/Bottom Frames with the felt facing the Screen Panel
3. Screw the Computer Support Middle Brace Frame into the Computer Support Middle Frame, perpendicular to the end
4. Stick a strip of adhesive backed felt tape to the Computer Support Middle Frame



Assemble the Base. Proceed to screw together:

- a. Base Left/Right Panels onto Base Bottom Panel, screwing into the Base Side Bottom Frame pieces.
- b. The Screen Panel should now slip between the Base Left/Right Panels.
- c. Screen Top Frame (using 1 1/2" screws) into the tops of the 2 Base Back Side Frames.
- d. The left side of the Screen Panel into the back end of the Control Left Frame.
- e. Base Bottom Panel into Screen Bottom Frame (from the bottom).
- f. Base Front Panel into the front ends of Control Left/Right Frames and Base Side Bottom Frames.
- g. Control Back Frame (with attached Control Panel) into Screen Panel from the back of the Screen Panel ensuring that the USB cable is routed through the gap on the bottom left of the Screen Panel.
- h. Base Back Panel into Base Back Side Frames, flush with the bottom of the Base.



Install the computer middle support

1. Open the computer up flat and slide it into the top/bottom supports. While holding the hinge area up against the Screen Panel, insert the L-shaped middle support piece and push it up against the computer hinge area. While maintaining pressure on the the computer, screw the middle support in place through the Base Left/Right Panels.

Connect the Hood and Base chunks

1. Slide the Hood over the Base ensuring that it's pushed down snug.
2. Drill pilot holes into the Base Side Bottom Frames using the holes in the bottom tips of the Hood Left/Right Panels as a guide.
3. Remove the Hood from the Base and screw the 2 hanger bolts into the pilot holes you just made.
4. Put the Hood back on, flexing the Hood Left/Right Panels out until the hanger bolts are in the Hood Left/Right Panels' holes. Screw on 2 wing nuts to the hanger bolts to connect the Hood and Base together (make sure that the LED strip cable is routed



Mount the backpack frame

1. Tape or velcro down the battery pack for the LED strip to the bottom of the Base. Tie the 4-pin connector cable coming from the battery to the top of the backpack frame. This will allow you to easily connect/disconnect the Hood from the battery for chunk separation.

2. Refer to the photo at right for the approximate placement of the straps in the frame. The three longer straps go on the top and bottom, and the shorter straps on the sides. Thread the straps through these locations in the frame and through the matching slots in the backpack. The bottom of the backpack frame should be above the Base Back Panel.



VIII. Use

Starting it up

1. Power up the laptop. Adjust your power settings to maximize both screen brightness and battery longevity. If you don't have a bluetooth keyboard, start your game and keymapping software. Slide the laptop into the Base.
TIP: We drilled a small hole in the center of the Screen Panel over the power button to allow us to press it with the laptop installed
2. Plug in the Control Panel USB cable.
TIP: Hand-held USB controllers can be plugged in and hung in pouches from the wing nuts on either side of the backpack.
3. Slide the Hood over the Base ensuring that it's pushed down snug and secure with wingnuts.
4. Connect the two sides of the 4-pin connectors at the top of the backpack frame to power the LEDs.

We've had the most fun using the backpack at various nighttime outdoor gaming events. A helper with a bluetooth keyboard is useful for fixing crashes, explaining the backpack to players/viewers, and as general support for the backpack wearer.

