Caveatron Rev C Assembly Instructions

Version: 2023-01-26

Overview

This document provides instructions on how to assemble the Caveatron Rev C – the version based on the Teensy 4.1 microprocessor. This version has a 3D printed enclosure and a custom printed circuit board (PCB) and requires cutting at least one acrylic part and soldering items to the PCB including a few smaller surface-mount components.

Some Tools Required:

- Band Saw (or other tool for cutting plastic)
- Soldering Iron
- Screw drivers
- Pliers
- Tweezers

Assembly Materials Required:

- Marine grade or flexible waterproof adhesive
- O-ring epoxy
- O-ring lubricant (synthetic grease)
- Soldering supplies including heat shrink tubing
- Adhesive-backed foam
- Tape (Kapton or electrical)

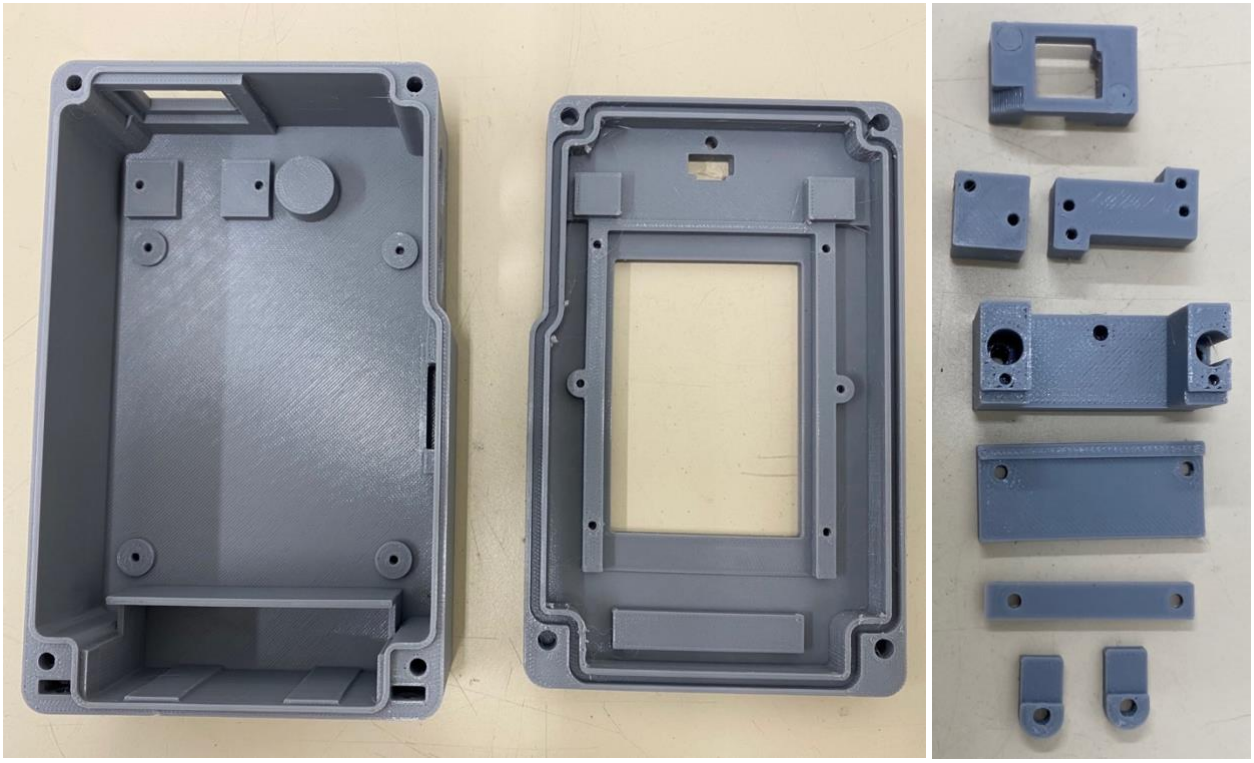
Main Enclosure

3D Printed Parts

The main enclosure body parts are 3D printed. Detailed information about the parts and printing them can be found in the separate "Caveatron Rev C 3D Printed Parts Description" document. The recommended material is PETG which is more durable than PLA, but more flexible and easier to print than ABS. If the goal is to maximize durability, then ABS would probably be fine, but I would not recommend PLA.

There are 10 printed parts needed (9 unique parts) as summarized below and shown in the photo:

- Main Enclosure Base
- Main Enclosure Lid
- LRF Cradle Bracket
- LRF Clamp
- IMU Bracket
- Magnetometer Bracket
- Magnetometer Clamp
- Buzzer Clamp
- LCD Clamp (2 pieces)



3D printed parts for the main enclosure base.

Preparing the Parts

After printing the parts and removing support material, a small amount of sanding with a fine grit sanding sponge or sandpaper may be desired to clean up the edges – especially on the main enclosure to give the

edges a little more of a rounded edge for more comfort while holding it. There are sometimes residual stringing from the printing process that need to be removed.

Installing the Threaded Inserts

The parts have holes for either thread-rolling screws, for mounting smaller components, or for threaded inserts, where a more durable connection is required. Heat-set threaded inserts are installed using a soldering iron. Two sizes are used as indicated below:

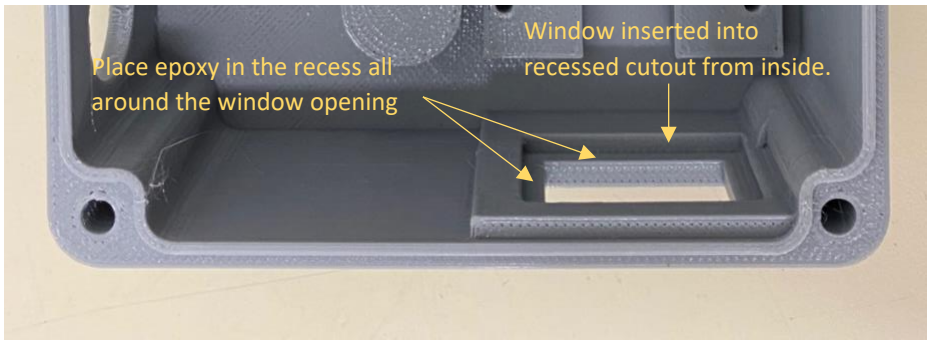
- #6-32
    - 4 in the under side corners of the Main Enclosure Lid – for attaching the base and lid
    - 2 on the top of the Main Enclosure Lid – for attaching the LIDAR module enclosure
- ¼-20 (optional - for tripod mounting)
    - 1 on the underside of the Main Enclosure Base

Before installing the inserts, have a matching screw ready to check that the insert if vertical. To install them, hand press them as far as you can into the hole and give them a few light taps with a tool. Press the soldering iron onto the top of the insert for a few moments to allow it to heat up the part and then start gently pressing and slightly wiggling the insert to encourage it to move deeper into the hole. Be careful not to the let the soldering iron slip and damage the 3D part surface. Keep pressing and wiggling until the insert is level with the top surface of the part as shown below. Remove the soldering iron and quickly thread in the matching screw a short distance and look to confirm that the screw sticks straight up from the surface. Be careful since the inserts are very hot! If it is angled by any significant amount, try to use the screw to straighten it out before the plastic cools and re-hardens. Otherwise leave in the screw and use the soldering iron to warm it back up to correct it (be careful to avoid getting burned).

Use a large tip soldering iron to install the inserts. As shown in the photo at left, tilt the soldering iron along the edge of the insert or use a wide tip to be sure to not get the tip stuck inside the insert or it will pull out the insert once you have pressed it in. Be sure that the inserts are installed level with the surface. Use a matching screw to quickly confirm that the inserts are installed vertically and not tilted. If you are fast enough you can use them to correct any tilt before the plastic cools down. Be careful as the inserts are very hot!

LRF Window

There is 1 clear acrylic part that must be cut out and installed for the LRF window. This window uses 0.09" thick material. After cutting it out, test the cut piece by placing it in the cutout position. Once you are satisfied with the fit, it is time to glue it into place. Use a marine grade or other waterproof adhesive – I use Flex Seal Flex Glue https://flexsealproducts.com/products/flex-glue. Place the epoxy on the inside walls of the enclosure window cutout. Put in just enough to get continuous coverage but not too much or it will ooze out when you insert the window. This is best done using a syringe to get a thin bead around the interior of the recess as described on p. 15 and 16. Use a glove to press the window into place so as not to get fingerprints on it and being careful that no epoxy gets on the center part of the window. Press it tightly for several minutes to allow the epoxy to set up and clamp it. Allow it to cure for 24 hours.



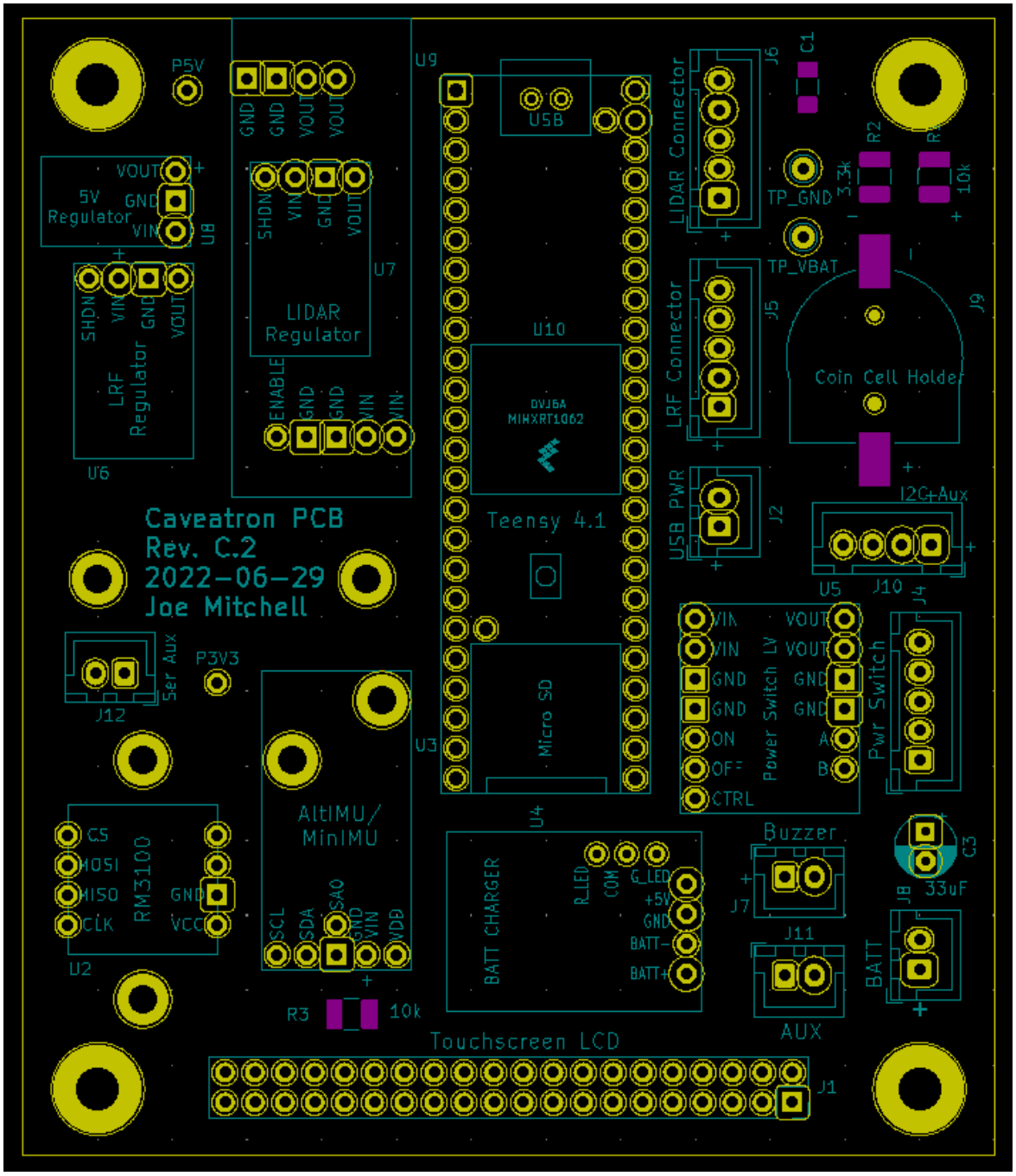
LRF Window Cutout: Place epoxy around the perimeter of the recessed window cutout and fully press the window into the cutout. It should be flush with the perimeter of the cutout.

Wire Harnesses

Detailed instructions for preparing the wiring harnesses can be found in the separate "Wiring Harness Assembly" document.

Electronics

Some electronics modules are intended to be attached to the printed circuit board (PCB) by plugging them into a female header while others are to be directly soldered onto the board. All of the components will need male header pins soldered onto them as well, though for some components, only selected pin locations are populated. Also, not all pin locations on the PCB are used. This is described below.



Schematic of Caveatron Rev C PCB

Teensy 4.1

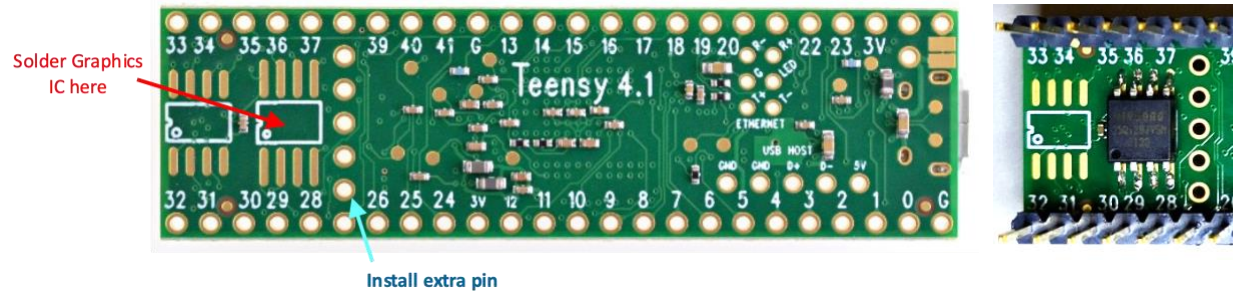
The Teensy needs to be modified to add the Font/Graphics IC (SPI flash memory chip) and at least 1 header pin.

A Winbond SPI flash memory IC is used for the Font/Graphics IC and is soldered directly to pads on the backside of the Teensy board. There are two pad positions – be sure to use the slightly larger pad position further from the edge as indicated by the red arrow in the figure below. Before soldering, be sure the indicator dot on the SPI flash IC is aligned to the silkscreen dot on the Teensy board. Soldering an 8-SOIC

package is best done by using tweezers to align the IC hold then press it down to the board. Get a small drop of solder on a small soldering iron tip and apply it to one pin while continuing to hold it down and brush it outward along the pad away from the IC to get a smooth line of solder from the pin to the pad. Once one pin is attached, double check the alignment, then solder each of the other pins. A picture of the SPI flash attached to the board is shown below.

If you ordered it with pins pre-soldered, you need to add one additional male header pin at the Vb (1x1) position for the real-time clock (RTC) battery. If you ordered it without pins, then you will also need to solder both full edge rows with a 1x24 set of pins. On the PCB, two 1x24 rows of female header sockets are soldered to the board along with one 1x1 female header sockets under Vb.

For the USB connection to the Teensy board, the USB Data/Power wiring harness that you create has a USB micro connector soldered to one leg of wires that you simply plug into the Teensy.



Teensy 4.1 Board. In addition to all of the 24 pin along both sides, the pin marked with the blue arrow must be populated with a male header. The Graphics IC (SPI flash memory module) is soldered on the pad indicated with the red arrow at left and shown after soldering in the photo at right.

Voltage Regulators (5V)

All pins on this board are populated with a 1x3 male header and is soldered directly to the PCB at the location marked “5V Regulator”. Pay special attention to be sure to get its orientation correct.

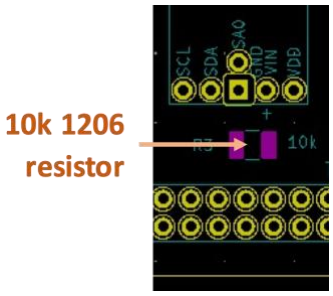
Voltage Regulators (LRF)

All pins on this board are populated with a 1x4 male header and is soldered directly to the PCB at the location marked “LRF Regulator”.

MinIMU/AltIMU

All 5 pins along one edge of the board are populated with a 1x5 male header and it is plugged into a 1x5 female header socket that is soldered to the PCB at the location marked “AltIMU/MinIMU”. (The inset SA0 pin is not used.) This component is additionally attached to the PCB with the IMU bracket. Since the orientation of this component is important, the following procedure should be followed. First solder the female headers to the PCB. Insert the male headers into the socket without soldering them to the IMU. Attach the IMU board to the IMU bracket with one (MinIMU) or two (AltIMU) 2-28 x 1/4” long thread rolling screws. Place the IMU and bracket onto the main PCB (with the tops of the pins through the IMU board pin holes) and attach the IMU bracket to the PCB with two more 2-28 x 1/4” screws from the underside. Finally, solder the pins to the IMU board.

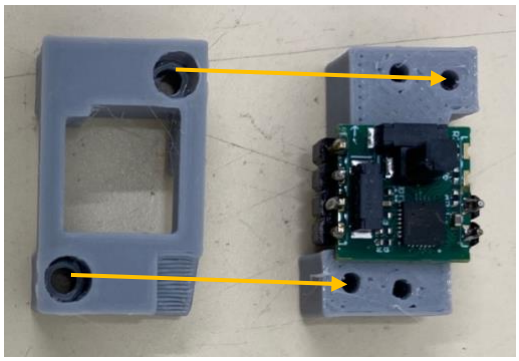
A location is provided next to the IMU pins on the PCB to solder a 10K surface mount resistor on the power inputs for the IMU (R5). This is highly recommended since the resistor prevents a problem where the IMU does not power up properly if the Caveatron is turned back on within a few seconds after being turned off.



Location of resistor for IMU module.

RM3100 Magnetometer

All four pins along one edge (CS, MOSI, MISO, CLK) have a 1x4 male header attached while on the other side, a 1x2 header is used for only the GND and VCC pins. On the Caveatron PCB, the equivalent female headers are used. 4.2 mm short female headers are used here since the RM3100 has some tall components. The RM3100 also needs to be aligned to the main PCB as best as possible. One method is to place the female headers in a breadboard. Then cut the length of the male header pins so that they fully fit into the female headers. Insert them into the female headers, then press the RM3100 board in between the pins. Now with it resting in between the headers, solder the male headers to the RM3100. Now, with the female headers still attached to the male headers, place it on the RM3100 base bracket. Attach the RM3100 clamp on top of the bracket base using two 2-28 x 0.25" thread rolling screws. Now place the assembly onto the Caveatron PCB at the location marked "RM3100" and insert the 2-28 x 0.25" thread rolling attachment screws from the rear. Do not fully tighten them yet. Attempt to align the assembly as square to the Caveatron PCB as possible, then tighten the attachment screws. Finally solder the female header pins to the Caveatron PCB from the rear.



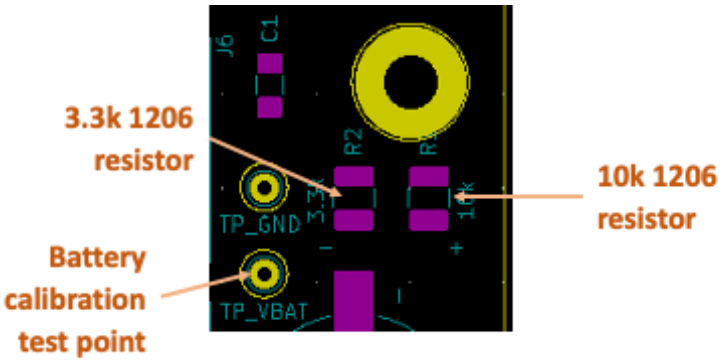
Attachment of the RM3100 bracket. Be sure the 4 pins are to the left and the sloped corner of the bracket clamp top piece is on the lower right.

Power Switch Board

For this board, solder a 1x6 male headers to one side and a 1x7 male header to the other side. This component is soldered directly to the main PCB at the location marked "Power Switch LV".

Battery Monitor Resistors

Two surface mount resistors are soldered to the two indicated pads to serve as the battery monitor (R1 and R2). Note that the two resistors have different values so be sure to install the correct one on the correct pads. A test point is also provided (TP_VBAT) to probe when calibrating the battery voltage when running Caveatron Setup.



Location of battery monitor resistors and test point for calibration.

Other Parts & Connectors

The coin cell battery holder is soldered directly to the PCB in the location marked “Coin Cell Holder” onto the surface mount pads. The plastic pins in the base of the battery holder align to the holes in PCB to hold it in place while soldering it.

A 2x20 female header socket is soldered to the PCB at the location marked “Touchscreen LCD”.

Three 5-pin JST connector sockets are soldered at the locations marked LRF (J5), LIDAR (J6), and Power Switch (J4). Four 2-pin JST connector socket are soldered at the locations marked BATT (J8), BUZZER (J7), and USB PWR (J2). Be sure to the note the JST socket key orientation as shown on the PCB silkscreen to install them correctly. The J10, J11, and J12 connectors are not used at this time.

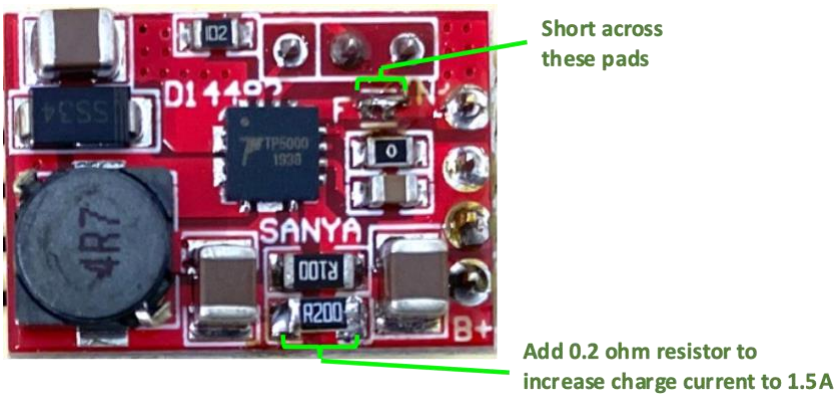
Note that the PCB has two capacitor locations (C1 and C3) which were included in case of power spike issues, but no issues have been observed so they are not presently used.

Prepare the Li-Ion Battery Charger Module

The component must have a small modification preformed before installation or it will not function. The two indicated pins in the illustration below must be shorted together either with a solder bridge or soldering a 0 ohm surface mount resistor.

The module has a default charge current of 1 Amp but the Caveatron battery can handle a higher charge current for faster charging. This module can handle up to 2 Amps but since it does not have a heat sink, 1.5 Amps is the maximum recommended. To adjust the current, add a resistor to the pads below the R100 resistor already on the board. Using a 0.2 ohm resistor will produce an 0.067 ohm combined resistance resulting in the 1.5 Amp charge current. If you are feeling risky (not recommended), an 0.05 ohm combined resistance gives a 2 Amp charge current and is obtained by a 0.1 ohm resistor in this spot.

The charger board has 7 pins attached, four on the short side for power and three small ones along the long side for the power switch LED. It is then soldered directly to the PCB at the location marked BATT CHARGER.

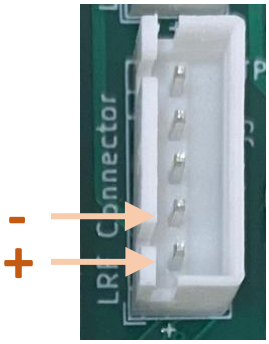


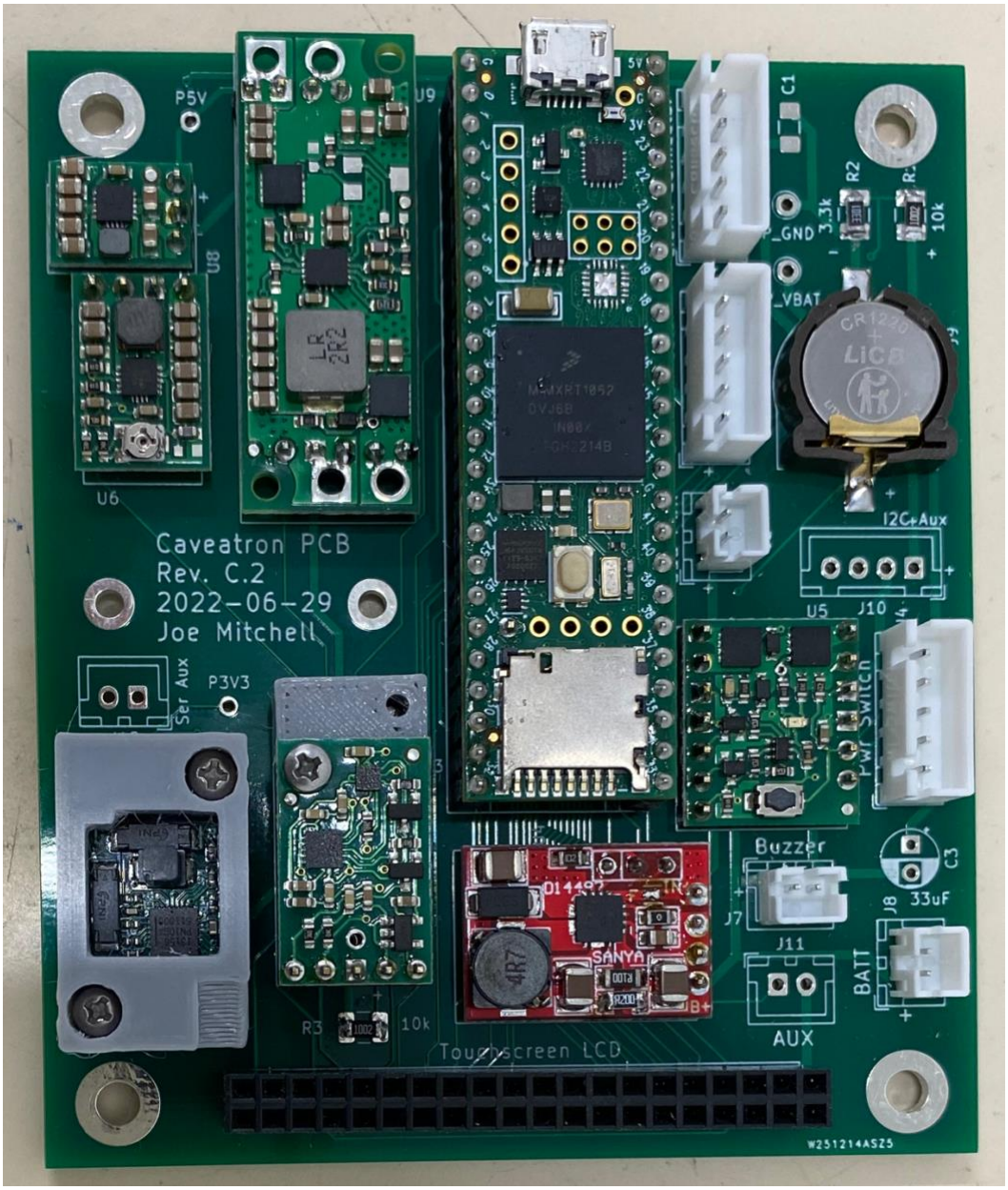
Li-ion Charger Module. The two pads indicated must be shorted together with a solder bridge or a 0-ohm resistor for it to function. The module has a default charge current of 1 A which can be increased to 1.5 A by adding a 0.2 ohm resistor across the bottom pads.

Set the LRF Regulator Voltage

Before attaching the LRF, the output voltage of the adjustable regulator that powers the LRF needs to be set. Assuming you have not yet loaded any code onto the Teensy, you should be able to do this by plugging in the battery and connecting a voltmeter to the two most interior pins on the LRF JRT connector (J5) - the plus voltage pin (marked on the PCB with a "+", right next to the J2 label) and the minus pin right next to it, or the VOUT and GND pins of the LRF regulator. Press the small button on the Power Switch module to turn the system on or off. Use a small screwdriver to adjust the pot on the voltage regulator until the voltage reads 3.0 volts.

To set the LRF regulator voltage, measure across these two pins.





PCB with all components installed.

Main Enclosure Base Assembly

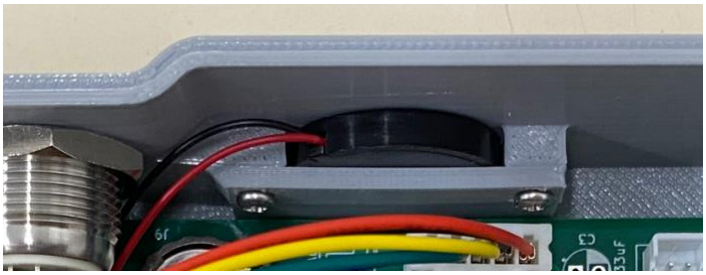
General note: When installing the thread rolling screws, it can be helpful to start the holes a little bit with the screw first before trying to install the part.

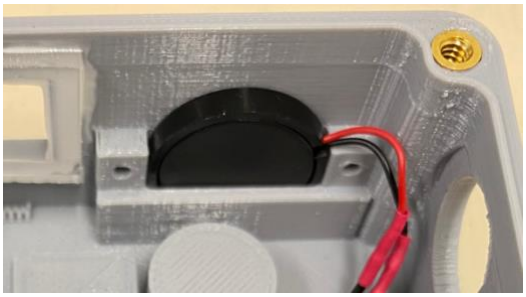
Circuit Board

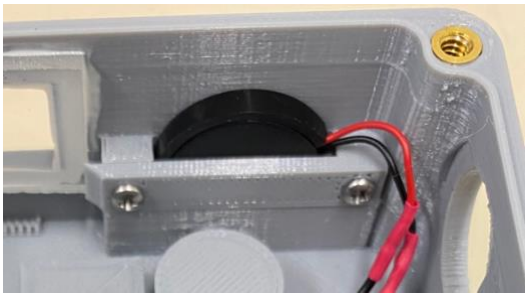
The main PCB must be installed first. Before installing it, trim off the extra pin lengths on the underside of the PCB being sure none stick down further than the height of the support points in the enclosure base. The main PCB is installed using four 4-20 x 1/4" thread rolling screws (one in each corner). Be sure that it is square to the enclosure by inserting each screw part way and then pressing back on the board from the front so that it is not skewed with respect to the walls.

Buzzer

The piezoelectric buzzer is installed into the slot along the side wall of the enclosure. The buzzer opening faces outward toward the enclosure wall. Press it into the slot and then install the buzzer clamp. Use two 2-28 x 1/4" thread rolling screws to attach it.



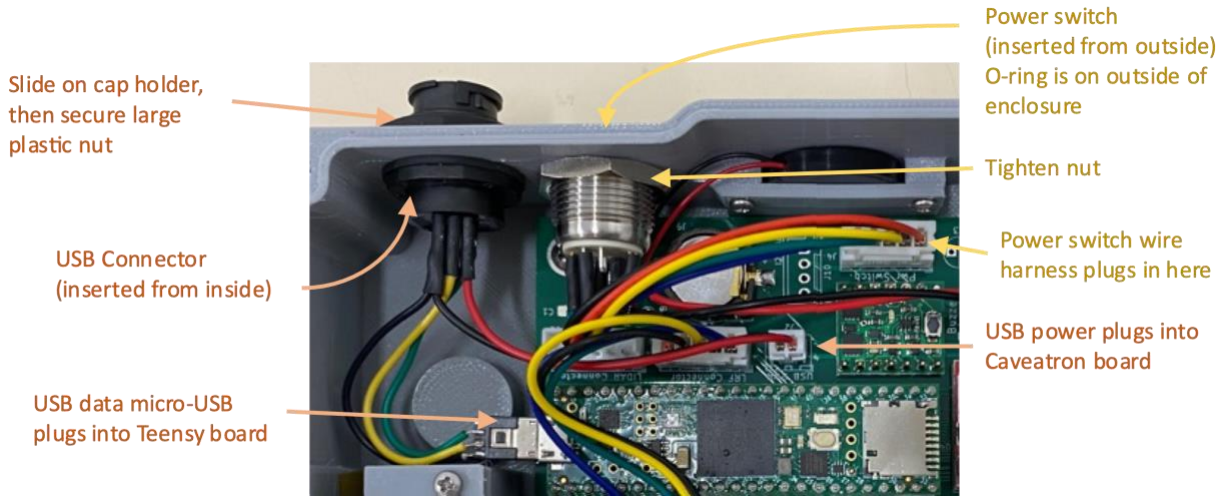




<u>Top:</u> Location of the piezo buzzer in the Rev C Caveatron. <u>Bottom:</u> The installation process (from a different model): insert the piezo buzzer into the slot (left) and then install the bracket (right).

USB Connector

The USB connector is inserted from the inside of the enclosure. It is keyed so it can only be inserted one way. Take the nut off first and be sure the gasket is in place on the connector. After sliding the connector into the enclosure hole, install the USB connector cover by sliding it over the threaded part of the connector from the outside. Be sure to position it, so the connecting piece is toward the bottom front as shown. Screw on the nut and tighten it down. Plug in the 2-pin data connector to the main PCB and the micro USB into the Teensy board.



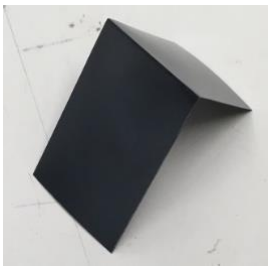
USB Connector and Power Switch installation and wire harness plug-in locations

Power Switch

The power switch is inserted from the outside of the enclosure as indicated in the photo above. Be sure the rubber gasket that comes with it is placed on the switch body before installing it. Once in place, slide the nut over the cable and thread it onto the rear of the switch and tighten it into place.

Position of the Power Switch, USB Connector, and USB Connector Cover as seen from the exterior.

Optical Filter

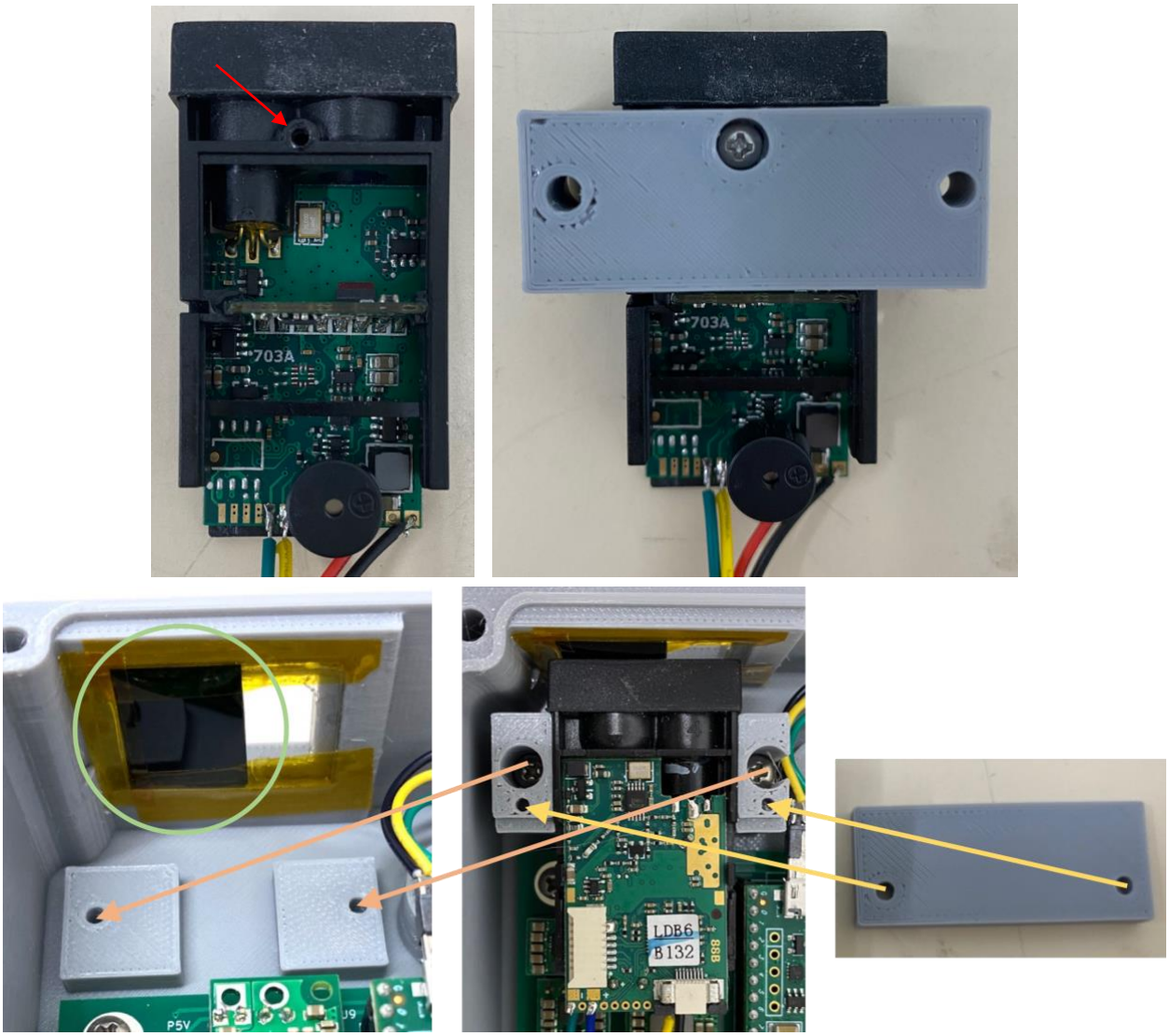


The optical filter blocks the receiver portion of the LRF to reduce the reflected light to cause it to only sense reflections from the retroreflective card. Cut a piece of the optical filter material to about 34 x 20 mm. Fold in half so that it is 17 x 20 mm. Tape it to the inside of the window so that the right 8-9 mm (as seen from the inside) is not covered to allow the LRF laser to emit unobstructed while fully covering the LRF receiver lens. See the photo below at bottom left for an illustration.

Laser Rangefinder

The LRF is installed in a cradle bracket that is in turn installed into the main enclosure base. When installing be sure to try to get all the parts as square to the enclosure as possible. The first step is to attach the

bracket to the LRF. Look for a small hole in the front center of the LRF on one side as indicated by the arrow in the picture below. The cradle bracket has a countersunk screw hole which is aligned with the LRF and a 2-28 x 1/4” thread rolling screw is used to attach it. After the optical filter is installed, flip the cradle bracket over and align the two large holes with the holes on the LRF mount (visible in the pictures below). Attach it with two 4-20 x 1/2” thread rolling screws. Finally, install the clamp on top of the cradle bracket as indicated in the photo below with two 2-28 x 1/4” screws.

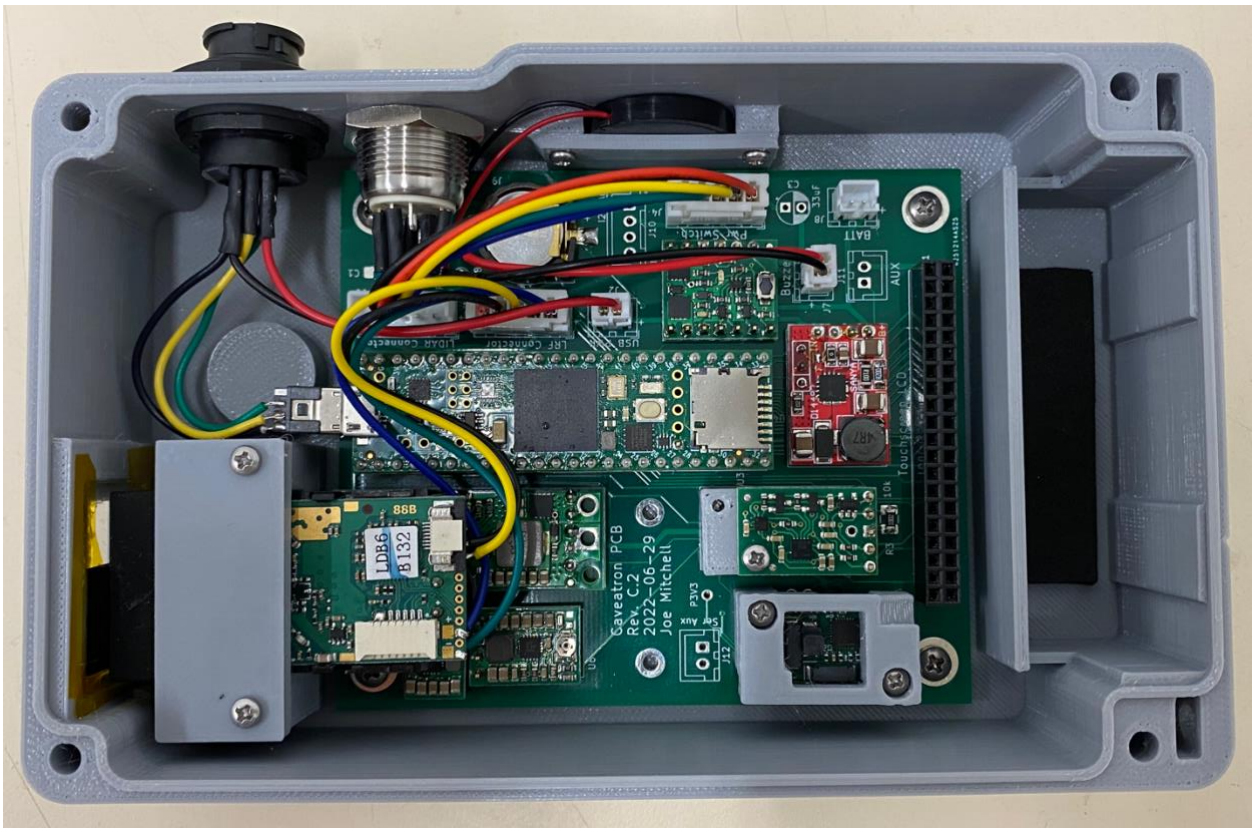


Installing the LRF. Attach the LRF to the bracket cradle (upper right) from the underside with a screw into the hole indicated with the red arrow (upper left). Next, install the optical filter (circled in green at lower left) by taping to the window as shown. Flip the LRF assembly over and install it in the enclosure with two screws that will go through the two large holes (lower center to left) and to the location in the base shown by the orange arrows. Finally, the clamp (lower center) attaches to the top with screws in the two small holes as indicated by the yellow arrows (lower right to center).

Battery

The battery goes in the large slot in the rear of the enclosure. To be sure it is tightly held and cannot slide around, a piece of adhesive backed foam can be placed along the bottom of the battery slot. Orient the battery and insert it so that the wire harness goes through the slit on the right front corner of the battery slot (as viewed from the rear of the enclosure). The battery will be fully secured by the lid.

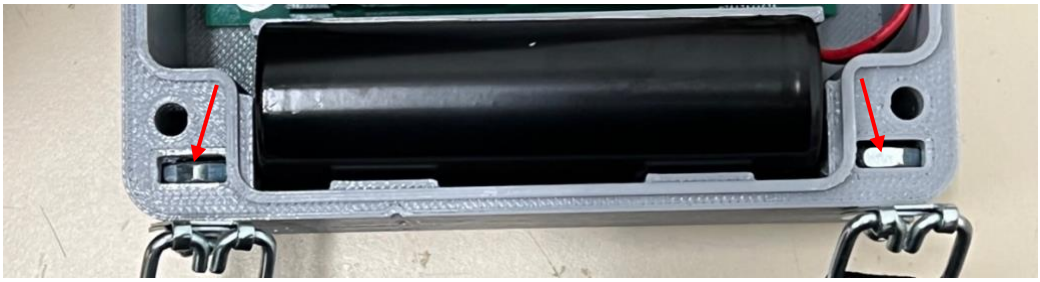
Complete the enclosure base by installing the CR1220 battery into the coin cell battery holder. Plug in all connectors except for the battery which will be plugged in during final assembly. Be sure all wires are routed and reasonably secured.



Main enclosure base with everything installed, except the battery which goes into the large slot on the right side in this photo and is shown installed in the photo on the next page.

Neck Strap D-Rings

Place a 6-32 nut into each of the two slots at the rear of the enclosure base as shown in the photo below. Use 6-32 x 3/8” screws and place a locking washer on each. Insert them through the hole in the D-rings being sure the flatter side of the D-ring mount is against the enclosure. Tighten them down securely into the nuts.



Installed neck strap D-rings with the nut locations indicated by the arrows.

Main Enclosure Lid Assembly

Touchscreen LCD Display

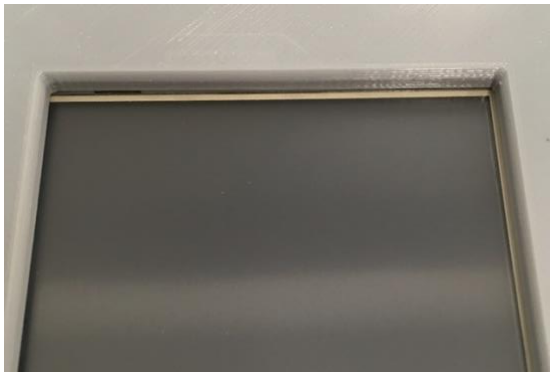
The touchscreen LCD display goes in the lid of the Main Enclosure and connects to the main PCB by a 40-pin ribbon cable. Start by installing the screen protector which must be cut to size. The screen protector in the Bill of Materials is the correct width and only needs to be cut to the following length:

Screen Protector Length: 3 5/16”

Now remove the protective film on the display. Be careful not to touch the display or get any dirt particles on the display until you get the screen protector installed. For the screen protector, peel the cover film off of screen side, being sure not to touch or get any dirt particles on the exposed part of the protector. Install the protector, lining it up with the bottom end of the LCD (the end opposite the pins). Be sure to line it up with the actual top end of the display module (covering the white frame part) which is slightly beyond the end of the actual screen – this gives it a bit more coverage for the silicone to seal to it. Slowly lower the protector across the length of the display, keeping it aligned to the edges and not getting bubbles in the middle of the screen. Once on, smooth out the edges and then peel off the top covering on the protector and smooth out again if you need to.

Cut the screen protector to length (at left with cut piece on the bottom) and place it on the screen (right). Be sure that the top of the protector is aligned with the white frame that is surrounds the display.

Before installing the screen, check the fit. Place it in the cutout as shown and be sure the screw holes line up. For best fit, slide it as far toward the front as possible (the end with the slot for the LIDAR module cable). When viewed from the top, you should not see any of the white frame of the display module, as shown below. Pull out the display and prepare to place silicone or epoxy sealant around the display perimeter. A syringe is recommended (I use these 18 gauge needles: www.amazon.com/gp/product/B07Z7MLFCZ) but you could use a toothpick or other method – just be sure to get a thin, smooth bead all the way around the edge so that you get continuous coverage as shown. Don't put on too thick of a bead or it will ooze out from under the screen edges when you screw it down in the next step.



Incorrect –

white frame is visible

Correct –

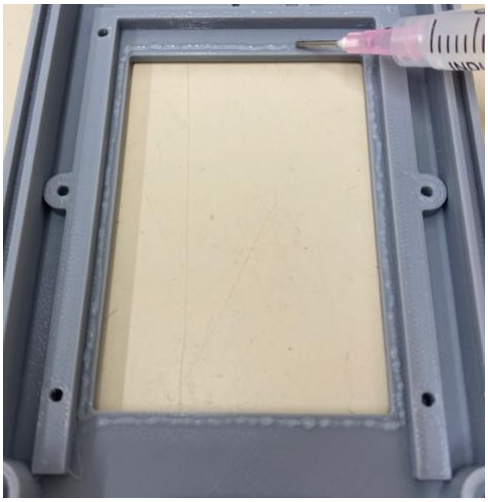
white frame is not visible

Positioning the touchscreen module – from the back when inserted into the cutout (left) and positioning with the white frame not visible from the front – incorrect (top right) or correct (bottom right).

Once the sealant bead is applied, line up the display at the front end so that you can tilt and press it down at the right spot in the cutout in a single movement (if you have to slide it, you might end up smearing silicone onto the visible part of the screen). Use four 4-20 x 1/4" thread rolling screws – one in each corner to secure it. Note that the holes in the LCD module are a little bit small and you will need to use a little bit of force to get the screws to go through. Start, but don't tighten these down until you have all screws started. Finish tightening them. Now insert two more 4-20 x 1/4" screws into the touchscreen display clamps, as shown, so that the lip on the clip will go over the display module PCB when

LCD clamp screw orientation

inserted. Install and tighten the screws. Check the topside of the screen and clean up any excess sealant. Allow the sealant to cure.



Add a silicone or epoxy sealant bead around the inside of the display cutout in the main enclosure lid (left). The screen installed from the backside (right) with screws and the clamps. Be sure not to put on too much sealant so it does not ooze out onto the screen and clean up any that does.

Add one or more piece of adhesive backed foam to the raised area at the rear of the lid (as shown at the bottom of the above right photo) and test it until it press down on the battery enough to hold it in place but not so much that the lid does not close properly.

O-Ring Gasket

A custom O-ring gasket is needed for the inside of the lid. This is cut from gasket cord and glued on the cut ends into an O-ring using O-Ring epoxy (regular cyanoacrylate can be used as well). Cut to the following length:

- **39.5 cm**

When epoxying the ends together, be sure to get an aligned joint. After the epoxy has cured for a few hours, smear a bit of lubricant along the length so that it will go in more easily and improve the seal. Press

the O-ring into the slot starting at one location and working around the perimeter. Work it in so that it is consistent and not sticking out or pressed too far in at any location.

On the top of the lid, a second small O-ring gasket is needed to seal to the LIDAR module. This is a standard O-ring part, size 114 with a 5/8” ID and a 13/16” OD. If you cannot find this part, you can fashion one from the O-ring material.

LIDAR Module Enclosure

3D Printed Parts

Detailed information about the parts and printing them can be found in the separate “Caveatron Rev C 3D Printed Parts Description” document. Parts are prepared in the same manner as the main enclosure described above with the differences listed below.

Depending on the specific LIDAR module, there are different parts required as summarized below:

- LIDAR enclosure base
- LIDAR enclosure lid

For RPLIDAR S2:

- LIDAR mounting bracket

For RPLIDAR A1M8:

- LIDAR enclosure lid top piece

RPLIDAR S2 enclosure base and bracket 3D printed parts.

Depending on the LIDAR module selected, different assembly instructions are used below.

RPLIDAR S2

Preparing the Enclosure Base

Threaded inserts are installed into the corners of the base enclosure using the procedure described on page three:

- #6-32: 4 inserts, one in each corner for lid

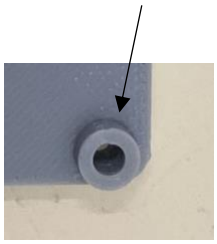
Take a 6-32 nut and press it into the location inside the LIDAR enclosure base shown in the photo at right.

Nut inserted into LIDAR enclosure base.

Installing the LIDAR

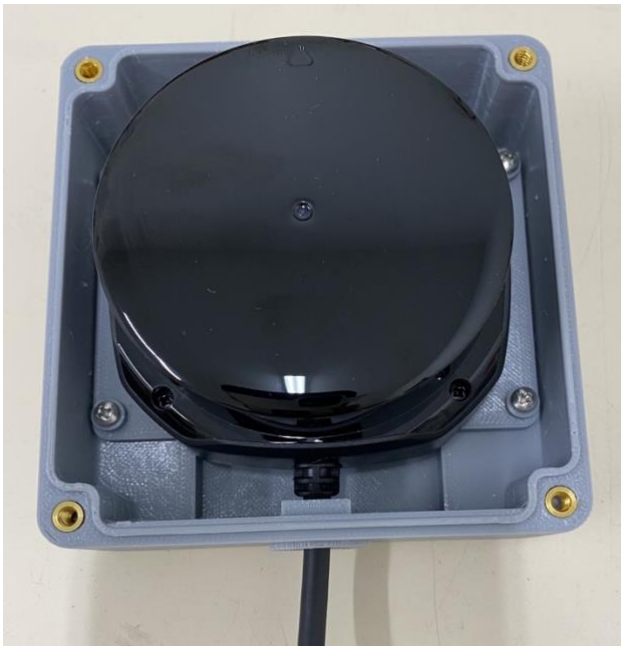
Mount the module onto the LIDAR bracket as shown in the photo below – the orientation on the bracket matters. The cable from the LIDAR needs to be oriented downward from the side of the bracket marked "CABLE" (the other edge of the bracket is marked "UP".) The LIDAR is mounted on the face of the bracket that has the small corner standoffs. Use four M3 x 6 mm pan machine head screws to attach the LIDAR. Set the LIDAR aside until the final assembly step.

The front side of the bracket, where the LIDAR module is placed, has small corner standoffs.



Bracket for the RPLIDAR S2. Be sure that the backside is the smooth flat face with the printed wording and not the face with the small standoffs. The version shown in the photo does not have the UP/CABLE indicators, which were added later, but the distance from the mounting screws to the edge of the bracket is slightly less on the side toward the cable.

Install the LIDAR bracket (with the LIDAR already mounted) into the LIDAR enclosure base. Route the LIDAR's cable through the slot in the base of the LIDAR enclosure. Turn the connector sideways so its protrusions go through the wider part of the slot. Pull it through as you work the LIDAR into position. Attach the bracket to the enclosure with 4-20 x ½" thread rolling screws through the slightly raised standoffs in each corner of the bracket.



LIDAR enclosure base with threaded inserts and S2 LIDAR module installed.

Preparing the Enclosure Lid

There are two different enclosure lid options for the RPLIDAR S2. One is open for the LIDAR lens to be exposed, but does have an O-ring that presses against the LIDAR body to provide some protection. The open design may not be completely waterproof and does leave the LIDAR lens exposed to impacts. The second cover option uses an acrylic dome that completely covers the LIDAR lens for maximum protection and to be waterproof. If you use the dome lid option, the dome is installed using the same waterproof epoxy as the LRF window as described above. Using a syringe or other implement, create a thin bead of epoxy around the groove inside the window through which the dome is inserted. Using gloves to protect the dome from fingerprints, press it into the opening and be sure the dome's rim seats fully within the groove. Clamp it down and allow it cure overnight.

Inside of the Dome lid for S2 LIDAR enclosure. The O-ring has not yet been installed.

For the outer lid gasket, cut the gasket cord and glue the ends into an O-ring using O-Ring epoxy (regular cyanoacrylate can be used as well). Cut to the following length:

- **35.5 cm**

Install it by the method described on p 17.

If you are using the Open Lid, you will need to create a second, inner gasket that presses against the LIDAR body. Cut to the following length:

- **23.5 cm**

Place the inner O-ring into the groove provided just outside of the opening. When you install it in a later step, the Open Lid will need to be installed carefully to prevent the inner O-ring from moving out of place as it is not tightly secured until installed.

Inside of the Open lid for S2 LIDAR enclosure with both the inner and outer O-rings installed. The upward direction of the lid when installed is indicated.

RPLIDAR A1M8

Preparing the base

- #6-32
  - 4 in LIDAR enclosure base corners
- M3
  - 4 inside LIDAR enclosure base in 3D printed standoffs

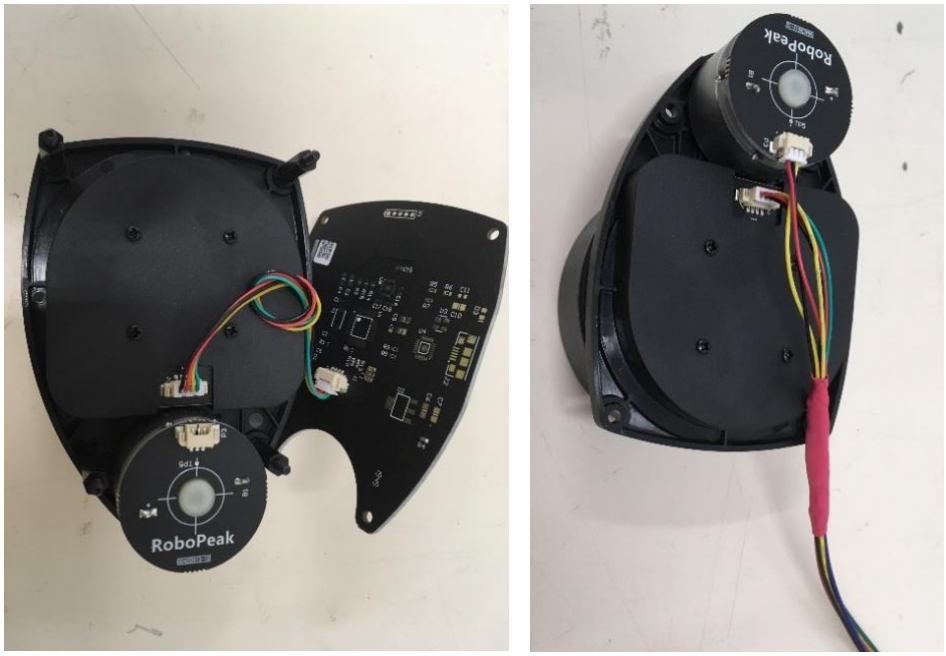
Take a 6-32 nut and press it into the location inside the LIDAR enclosure base shown in the photo on p 19.

Installing the LIDAR

Out of the box, the RPLIDAR A1M8 has a second board attached underneath the main module body. Remove this by unscrewing the lower part of the threaded standoffs and gently removing the two connector cables. You will not need this board.

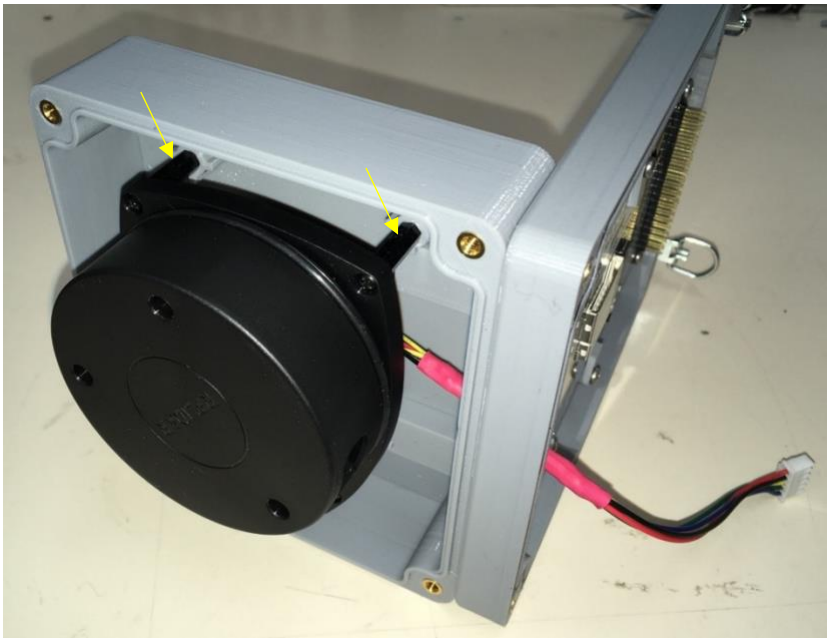
Unscrew the upper part of the threaded standoff from the main module by removing the screws on the top. Screw these four standoffs into the threaded inserts in the base of the Caveatron LIDAR module. Take the RPLIDAR A1M8 cable assembly and plug it into the two connectors on the underside of the RPLIDAR.

The A1M8 LIDAR installs using metal standoffs and screws that came with the RPLIDAR. Since the standoff posts may not be perfectly straight, its best to loosely install all the screws first before tightening them all down. First screw the threaded end of the standoff into the threaded inserts in the LIDAR enclosure base. Then align the LIDAR module to the inserts (the motor portion goes toward the left side when viewed form the front). Simultaneously, route the cable through the slot in the base of the LIDAR module enclosure. Turn the connector sideways so its protrusions go through the wider part of the slot. Pull it through as you work the LIDAR into position. Be sure the wire harness is not pinched and freely goes to the slot in the base. Insert the screws provided with the RPLIDAR through the holes into the metal inserts to start them. Then work your way around tightening the inserts and screws completely down



Partially removed lower PCB from the RPLIDAR showing the first of the two connectors disconnected (left). The LIDAR after installing the custom wire harness (center).

The RPLIDAR A1M8 module after being installed into the LIDAR Enclosure base and mounted to the Main Enclosure lid. The LIDAR module attaches to the black metal standoffs (arrows) which come with the LIDAR, that are in-turn screwed into inserts in the enclosure base.



Preparing the Enclosure Lid (Window version)

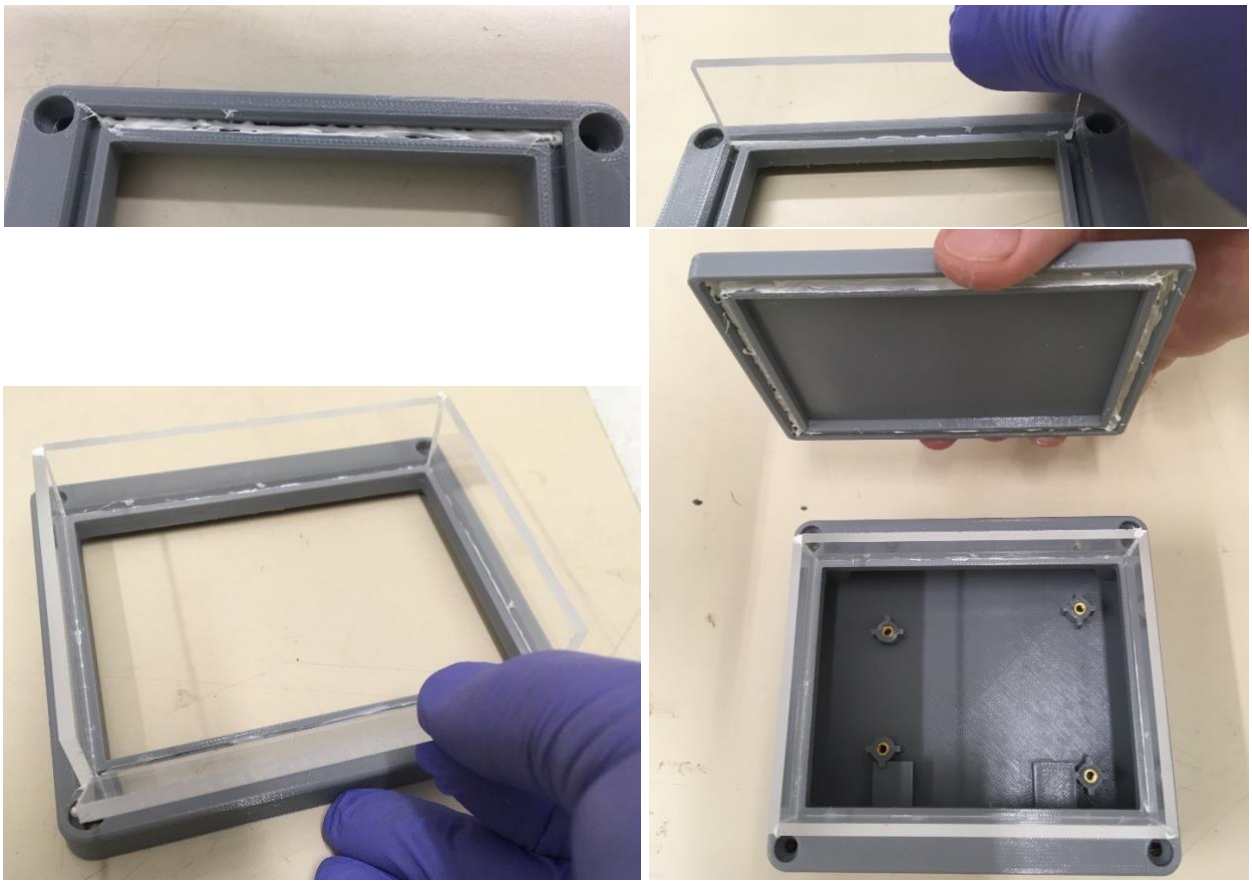
There are two lid options for the A1M8 LIDAR. One uses 4 clear acrylic windows to completely seal the LIDAR enclosure, while the other does not have windows so the enclosure is not sealed and exposed to dirt and water but blocks less of each scan. The sealed lid requires cutting out and installing 4 acrylic pieces using the 0.118" thick material. There are two lengths for the LIDAR module windows with the longer pieces forming the top and bottom while the shorter pieces form the sides. These pieces also form the mechanical connection between the two halves of the LIDAR module lid. When cutting them out, cut the lengths as precisely and as squared on the ends as possible since they must join together at the corners. Test the cut pieces by installing them in the slots in the RPLIDAR Module Base. The shorter pieces fill the full length of their slots, while the longer pieces go inside the shorter pieces.

Once you are satisfied with the fit of the pieces, it is time to glue them into place. Use a semi-flexible, waterproof adhesive. If you use a rigid adhesive, it will warp the windows, causing errors, and not result in a good seal. One method to dispense the epoxy is to use a blunt tip syringe. I use a 16 gauge syringe for the epoxy. Place the epoxy on the inside walls and base of the groove in the LIDAR module lid. Put in just enough to get continuous coverage but not too much or it will ooze out when you insert the window. Note the angled lip on the outside perimeter of the groove. That will be used later to add silicone sealant, so try not to get epoxy on that part. Use gloves to handle the windows so that you don't leave fingerprints on the inside. Be careful not to get any epoxy on the central portion of the windows.

Install the shorter windows first. Line the windows up with the groove and press them in, checking that they go in all the way and are level. For the longer windows, before installing them carefully place a bead of epoxy on the ends of these windows (the short edges). This will form the joint between the windows so it especially important to get a seal. Press these in at a slightly angled manner as shown in the photo below so that the epoxy on the ends does not smear too much. Once the windows are in, it will look like the photo below. Now add epoxy to the groove in the top of the lid. Note that the module lid base does

have a preferred orientation, though it is hard to tell by looking. The best way to check is to set it on the RPLIDAR module base and run your finger along the top or bottom. If it is NOT oriented correctly there will be a small step at the joint between the base and the lid. Check both ways for where this joint aligns the best. The top orientation of the LIDAR module base is shown in the photo. For the lid top piece, you want the Caveatron logo to be upright in this orientation. Once you are sure you have the orientation correct, press the lid top onto the windows. You may have to wiggle it a bit to get it to set the windows into the grooves correctly. Be sure everything is level and that the lid top is not at an angle to the base. Allow the epoxy to cure for 24 hours.

If you have gotten a good bead on the epoxy, you may not need to do the next step, but I have found that to be difficult to ensure. If you are not planning to use the Caveatron in a stream passage, its fine at this point and will provide sufficient protection against mud, dampness, and water on its surface. However, if submerged, water might force its way inside, so for extra protection, its best to add silicone sealant around the outside window joints. After the epoxy is cured, complete the sealing of the windows by using syringe (I used 20 gauge) to place the sealant into the angled edge of the groove around the outside of the LIDAR windows (both top and bottom sides) as shown. For good measure, you can add some across the corner joints as well. Try to get a nice continuous bead and be sure not to get any on the window. You can use a pointed toothpick to push it in further or spread out any blobs you might get if necessary.



LIDAR Windows: Place epoxy in the LIDAR window groove (upper left). Using gloves, press the windows into the grooves, doing the shorter windows first (upper right). Place epoxy on the ends of the longer

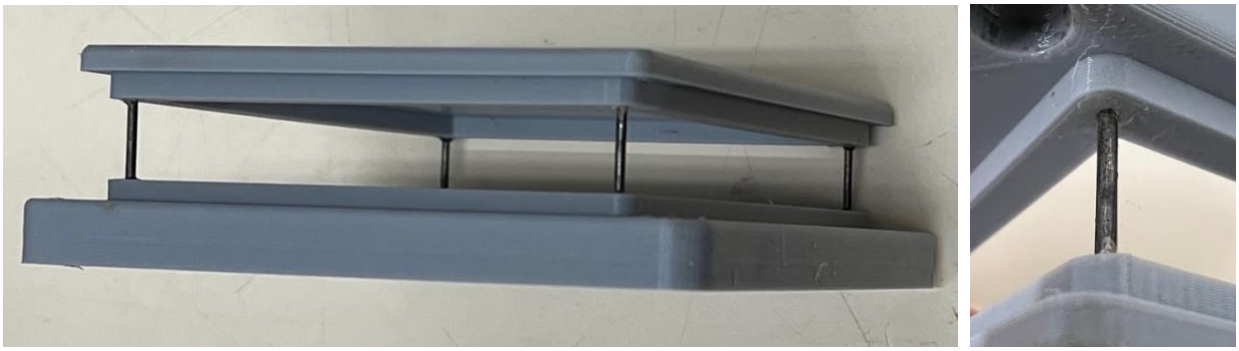
pieces and press them into place being sure to get them square (bottom left). Add epoxy to the grooves in the lid and press it onto the windows (bottom right). Be sure not to get epoxy on the exposed part of the windows.

Adding silicone sealant to the LIDAR windows for additional protection.

Preparing the Enclosure Lid (Non-window version)

The non-window version of the enclosure lid avoids the need to correct distortions introduced by the windows but leaves the LIDAR module interior exposed. To minimize the exposure and protect the LIDAR from impacts, a top piece for the lid covers the LIDAR and is held in place with small metal posts that minimize corner obscurations.

Obtain 1.5 mm diameter metal rod material (stainless steel is preferred). Cut four pieces to a length of 0.8” (20 mm). The enclosure lid bottom and top pieces both provide holes for the posts to be inserted. Apply a bit of epoxy to the post and insert it into the provided hole in the corners of the enclosure lid bottom. You may need pliers to fully insert it, but don’t press too hard or the metal may penetrate into the lid. Once all the posts are inserted be sure they are at approximately the same depth and adjust as needed. Now, place a small amount on the top of each post. Start with one corner and insert the post into the top piece corner hole. Work around each corner of the top piece until all the posts are started in their hole. Press down and adjust to get the lid top piece level with the bottom so there is a uniform opening all around. Allow the epoxy to cure.



The non-windowed version of the LIDAR enclosure lid with a closeup of one of the posts shown at right.

LIDAR Enclosure Lid O-Ring Gasket (both versions)

Cut the gasket cord and glue the ends into an O-ring using O-Ring epoxy (regular cyanoacrylate can be used as well). Cut to the following length:

- **37.5 cm**

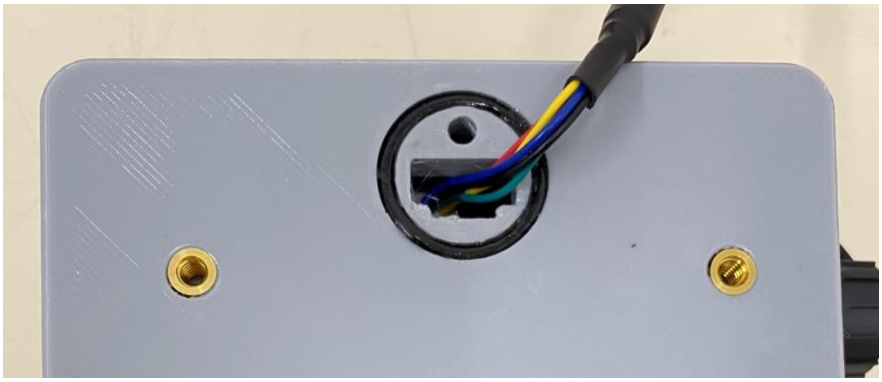
Install it by the method described on p 17.

Final Assembly

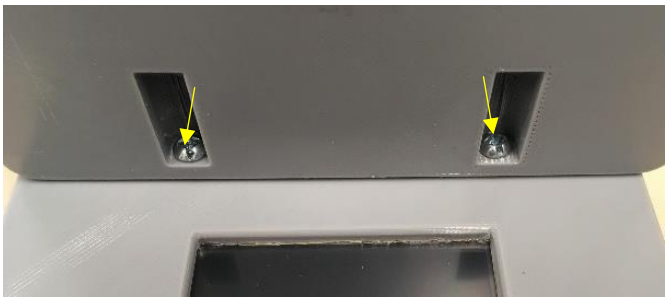
Attach LIDAR Enclosure

Insert the small O-ring into the groove on the top of the main enclosure lid. Insert the LIDAR cable into the square opening in the Main Enclosure lid and line up the hole in the front of the LIDAR enclosure base (with the nut) to the matching hole in the Main Enclosure lid. Get a 6-32 x 9/16" long pan head screw (5/8" will work as well) and insert it from inside the Main Enclosure lid. Screw it into the nut in the LIDAR enclosure base, but don't tighten it yet. Now line up the LIDAR Enclosure base so that the holes on its back side align with the threaded inserts on the top of the Main Enclosure Lid. Attach with two 6-32 x 3/8" pan head screws. Finally tighten down all three screws.

If you are using a lid with acrylic windows or a dome, double check that the inside of the windows are clean and free of dust. Blow it out or wipe it down if needed. Place the lid carefully over the LIDAR, being sure to get the orientation correct. Using four 6-32 x 3/8" (for the RPLIDAR S2 lid) or four 6-32 x 1/2" long flat head screws (for the RPLIDAR A1 lid), tighten down the lid until the corners of the cover just touch the base. The LIDAR module is now complete.



Inserting the LIDAR cable into the Main enclosure lid. The O-ring is already in place. Initially attach the LIDAR enclosure with a screw through the small hole inside the O-ring (screw inserted from bottom of lid). Then line up the rear holes with the two threaded inserts shown above in the lid.

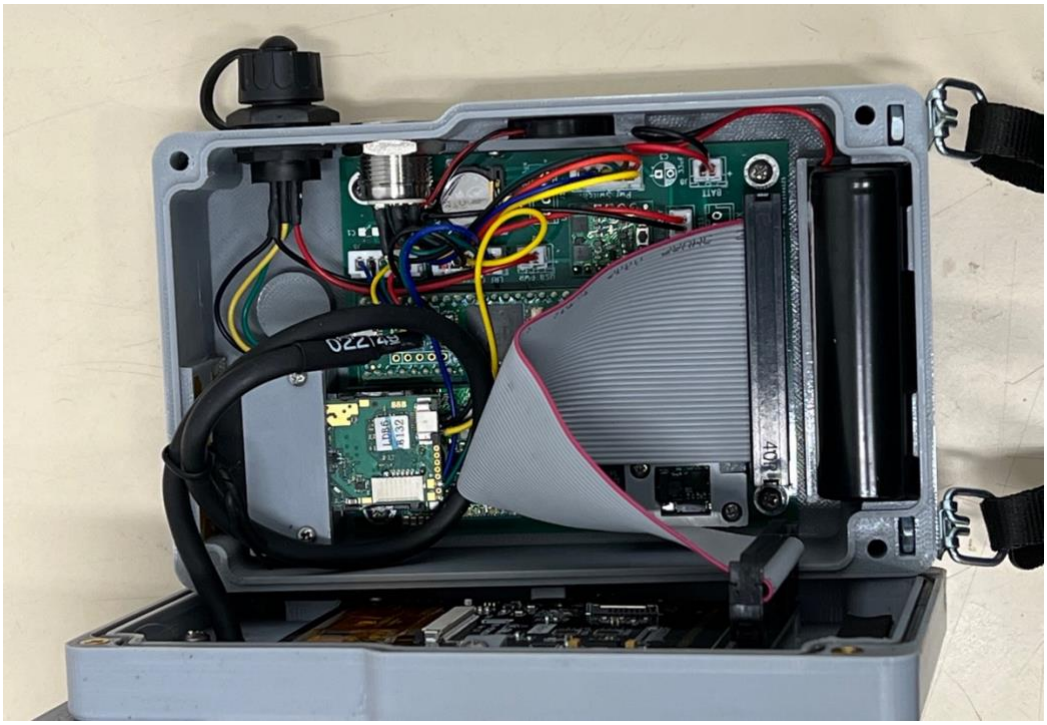


Finish the LIDAR installation by inserting screws where indicated by the arrows and tightening them down along with the front screw from underneath.

Main Enclosure Lid

Get the microSD card ready. Insert it into a computer and verify that it is formatted as FAT32. If not, reformat it. It is highly recommended to use the SD Association's official SD Formatter utility which can be downloaded here: https://www.sdcard.org/downloads/formatter/. Once formatted, copy the "cvfont32.bin" file to the microSD card so you don't have to remove the card later for the initial Caveatron software setup. Install the card in the Teensy's microSD slot.

Next, plug the 40-pin ribbon cable into the connector on the main PCB. Be careful that it's centered, since it's possible to accidently offset it to the side while plugging it in and have the pins offset by one position in the connector. The ribbon portion should extend toward the front over the main PCB away from the battery. Fold the cable in half so it folds back on itself with the connector on the other end pointing upward so that it can rest on top of the connector to the main PCB (see photo below). Be sure it has a good crease, so the fold is fairly tight and does not press down on the reset button on the Teensy.



Caveatron Rev C Final Assembly

Connect the other end of the 40-pin ribbon cable to the LCD Touchscreen module again being sure the pins are not offset. Finish by connecting the battery cable to its connector. Add a cable tie to any long or loose wires (such as tying up the long LIDAR cable) to secure them and prevent them from moving around.

Plug a USB cable into the external connector and connect it to a USB power source. The ring LED around the power switch should illuminate red. Now press the power switch and you should see several LED lights come on inside the box. If not, there may be connector or soldering issues.

Grease the O-ring on the underside of the lid and carefully lower it onto the base, being sure that all the wires are inside and not being pinched. Use four 6-32 x 1” flat head screws to attach it from the underside. Tighten these down until the corners of the lid just touch the base (due to the pressure of the O-ring as small gap will appear along the long side where the lid attaches to the base, but this is fine).

Neck Strap Lanyard

Install the neck strap onto the D-rings. Adjust it so the straps are evenly distributed between the two D-rings and it is not twisted. Adjust the length for comfort.

Neck strap attachment.

Charge the Battery

Plug the USB cable back in and fully charge the battery. When the ring LED on the switch turns green the battery is fully charged.

The Caveatron assembly process is now complete!

Reflective Card

Cut out the plastic card material to make a 6.25” x 7.5” rectangle. Round the corners by cutting and sanding. Cut out adhesive-backed retroreflective sheets or strips to make a 6” x 6” square. Place the retroreflective material on one side of the card so that it has a 1/8” border on three sides. On the side with the 1 3/8” border, install a 3/8” grommet near one corner as shown in the photo. To do this, cut or drill out an appropriately sized hole in the plastic, insert the grommet pieces and use a grommet tool and hammer to tap on the grommet until the pieces are attached to each other and the plastic.

The reflective card.

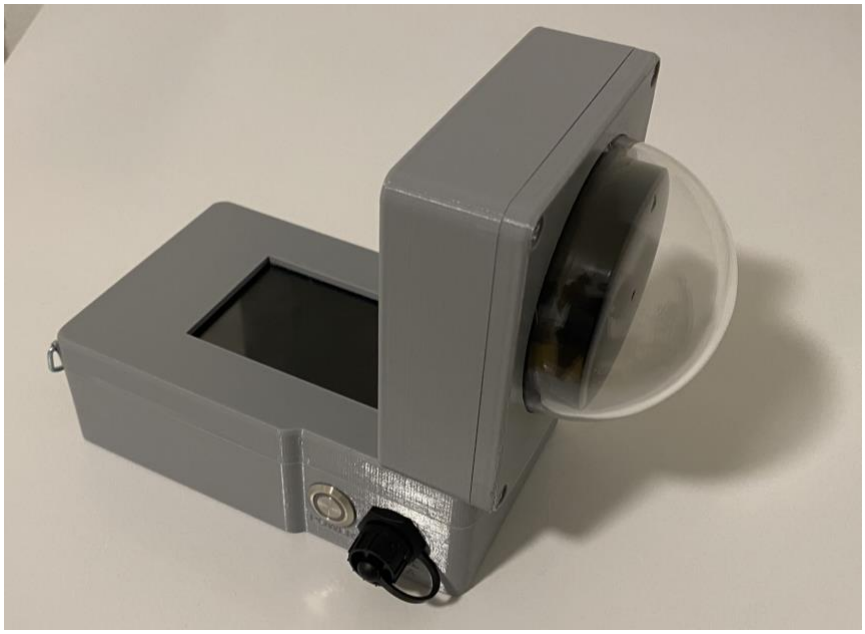
Software Installation and Setup

There are several steps remaining to prepare the Caveatron for use. These are described in other documents but the steps are summarized below:

- Prepare to load code into the Caveatron. Read the “Loading Caveatron Firmware” instructions and download the TyTools software.
- Load the Caveatron_Setup firmware appropriate for the Rev C Caveatron and run the setup process described in the “Caveatron Setup & Calibration Instructions” document.
- Load the Caveatron_v3xx firmware.
- Calibrate the Caveatron as described in the “Caveatron Setup & Calibration Instructions” document.

Your Caveatron is now ready to survey caves!

Fully assembled Caveatron Rev C with the open LIDAR lid.



Fully assembled Caveatron Rev C with the dome LIDAR lid.