Caveatron SV Rev C Assembly Instructions

Version: 2024-01-02

Overview

This document provides instructions on how to assemble the Caveatron SV – the non-LIDAR version focused on traditional sketch-based cave survey. This version has a 3D printed enclosure and a custom printed circuit board (PCB) and requires cutting one acrylic part and soldering items to the PCB including a few smaller surface-mount components. The Caveatron SV includes either an optional GPS module for marking entrances or surface features or an optional Bluetooth module that is planned be used in conjunction with the Android tablet-based sketch software, TopoDroid (but has not been implemented as this time.)

Some Tools Required:

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

Assembly Materials Required:

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

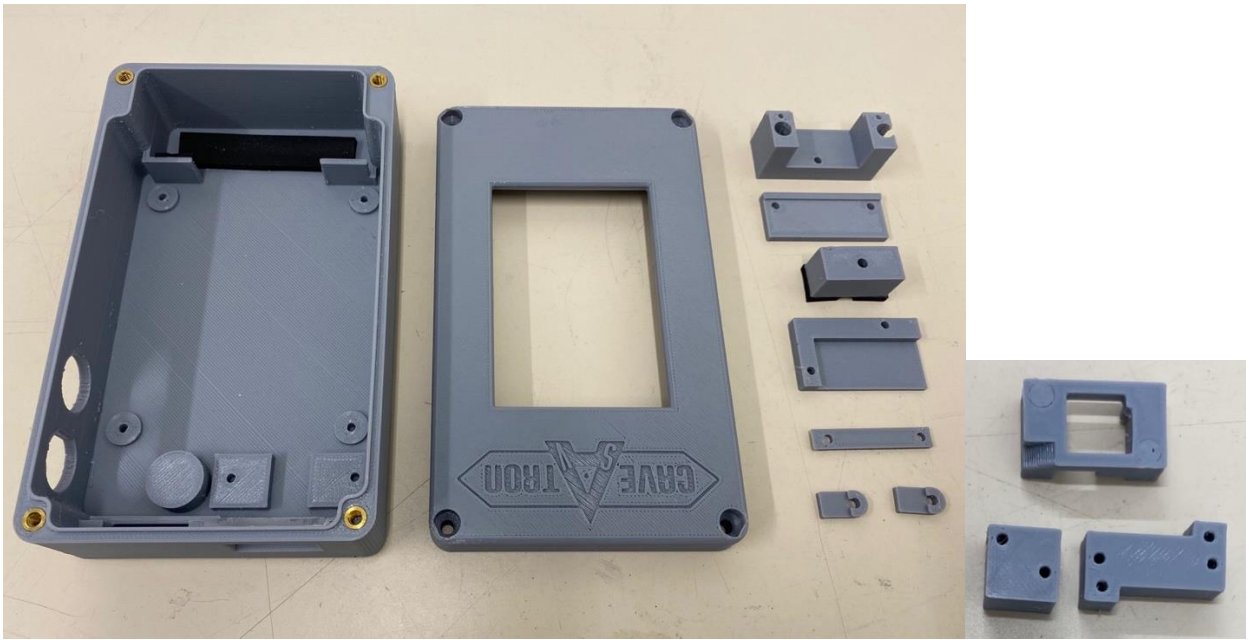
Enclosure

3D Printed Parts

The enclosure parts are 3D printed. Detailed information about the parts and printing them can be found in the separate "Caveatron SV 3D Printed Parts Description" document. The material I used is PETG which is much 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 12 printed parts needed (11 unique parts) as summarized below and shown in the photo:

- Main Enclosure Base
- Main Enclosure Lid
- LRF Cradle Bracket
- LRF Clamp
- IMU Bracket
- RM3100 Bracket
- RM3100 Clamp
- LCD Clamp (2 pieces)
- Battery Clamp
- Buzzer Clamp
- (Optional) GPS Bracket or Bluetooth Clamp



3D Printed Parts. Threaded inserts for attaching the lid are installed in the main enclosure base at left.

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 is 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 Main Enclosure Base top side corners for attaching the lid
- ¼-20 (optional - for external mounting)
    - 1 on the underside of the Main Enclosure Base

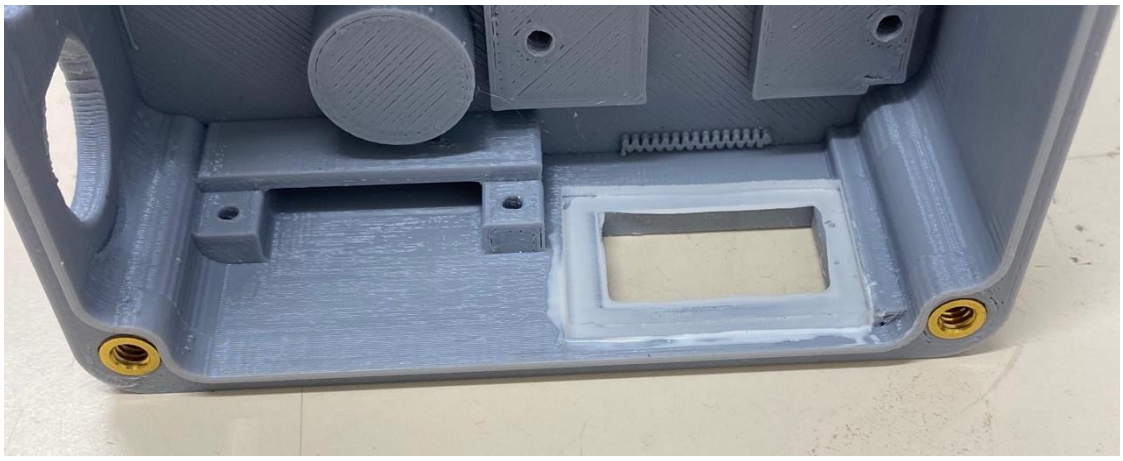
Before installing the inserts, have a matching screw ready to check that the insert if vertical. To install them, hand press them as far as you can into the hole and give them a few light taps with a tool. Press the soldering iron onto the top of the insert for a few moments to allow it to heat up the 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!

Acrylic Window

There is one clear acrylic window that must be cut out and installed for the LRF window. After cutting it out, test the cut piece by placing it in 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 suggest something like 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: Place epoxy around the perimeter of the window opening. Using a glove, press the window into place being sure not to get any on the open part of the window.

O-Ring Gaskets

A custom O-ring gasket is needed for 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:

- 15” (38 cm)

When epoxying the ends together, be sure to get an aligned joint. After the epoxy has cured, 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.

Wire Harnesses

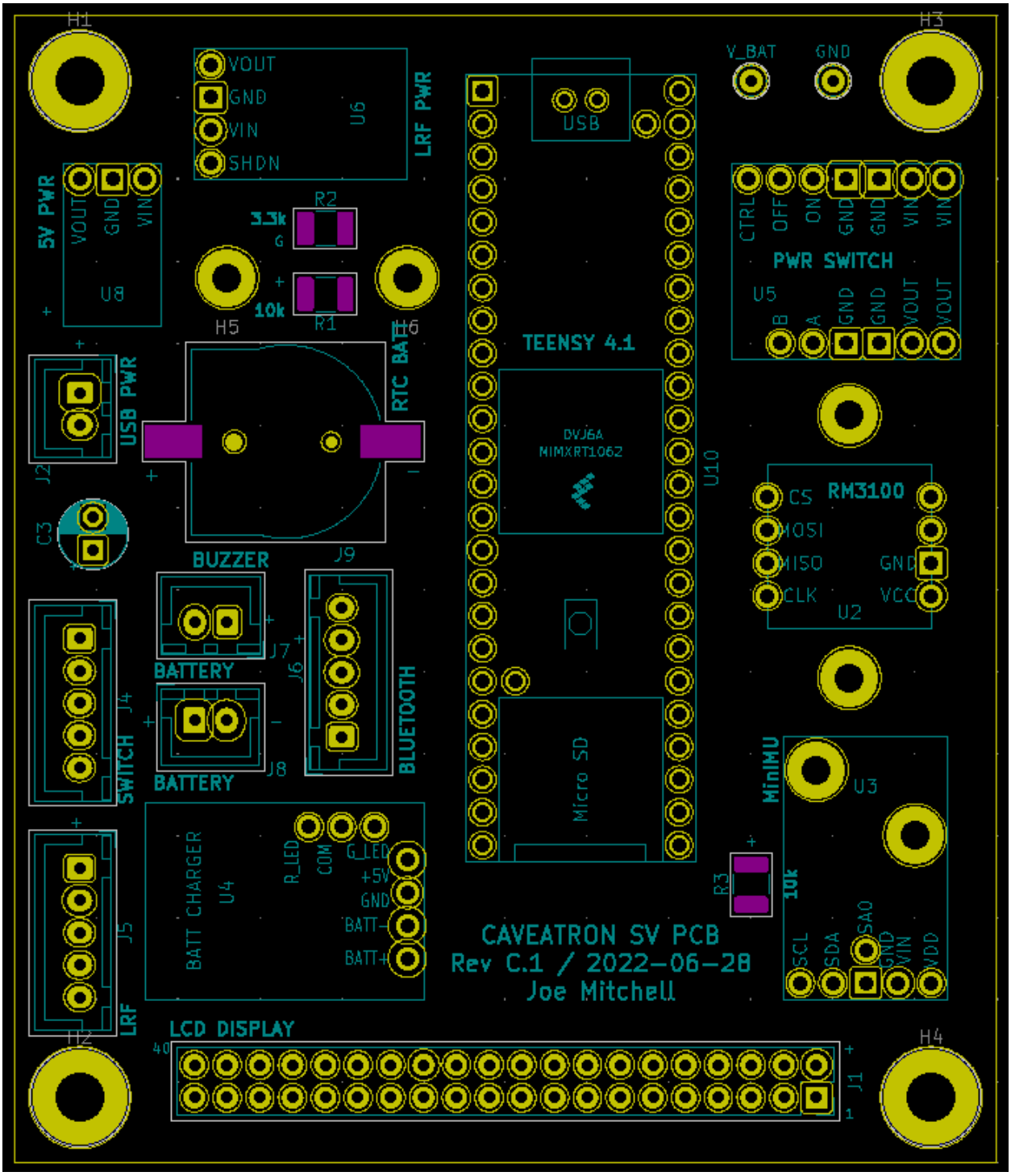
Detailed instructions for preparing the wiring harnesses can be found in the separate “Wiring Harness Assembly” document. There are 7 wiring harnesses:

- Laser Rangefinder
- USB Power
- USB Data
- Power Switch
- Piezo Buzzer
- Battery
- Bluetooth (optional)

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 SV Rev C PCB

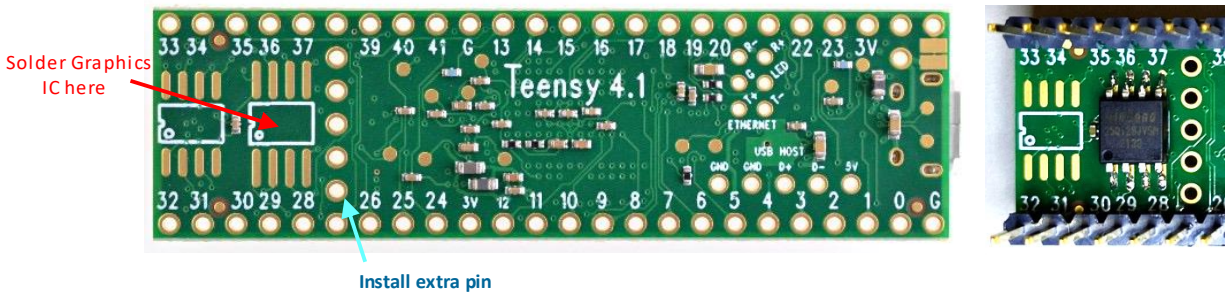
Teensy 4.1

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 PWR. Pay special attention to be sure to get its orientation correct.

Voltage Regulators (LRF)

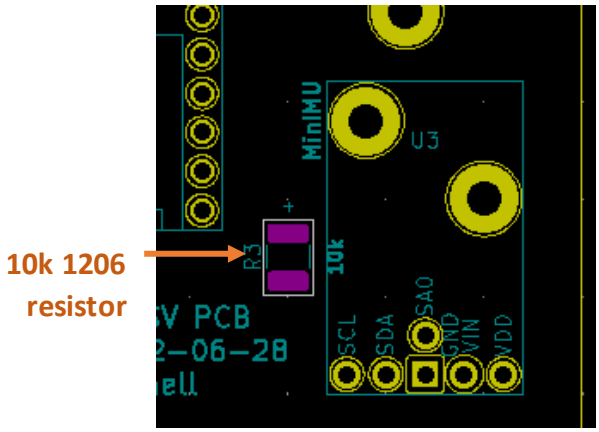
All pins on this board are populated with a 1x4 male header and is soldered directly to the PCB at the location marked LRF PWR.

MinIMU

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 ”MinIMU”. (The inset SA0 pin is not used.) This component is additionally attached to the PCB with the IMU bracket. Since the positioning

of this component is more important than the others (to get the compass orientation correct), 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 2-28 x 1/4" long thread rolling screw. 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.



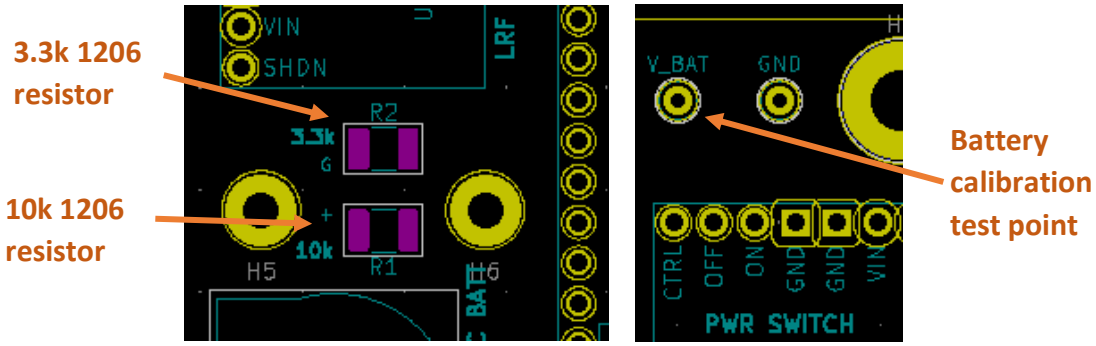
Location of resistor for IMU module.

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 PWR SWITCH.

Battery Monitor Resistors

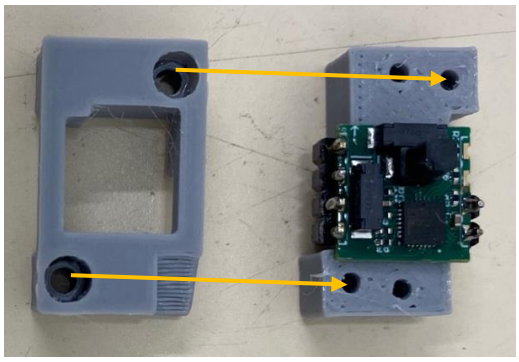
Two surface mount resistors are soldered to the two indicated pads to serve as the battery monitor. Note that the two resistors have different values so be sure to install the correct one on the correct pads.



Location of battery monitor resistors and test point for calibration.

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 SV 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 SV 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 SV PCB as possible, then tighten the attachment screws. Finally solder the female header pins to the Caveatron SV PCB from the rear.



Attachment of the RM3100 bracket. Be sure the 4 pins are to the left.

Other Parts & Connectors

Due to the short life of coin cells to power the Teensy RTC battery (about 45 days), it is recommended that you perform the RTC regulator retrofit modification instead of installing the coin cell battery holder. Instructions can be found with the regular Caveatron RevC documentation as a separate document entitled "RTC regulator retrofit". If you want to use a coin cell battery, the holder is soldered directly to the PCB in the location marked RTC BATT 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.

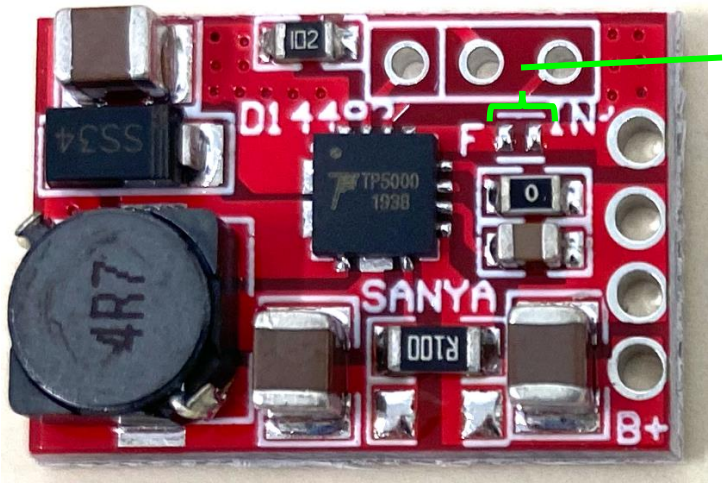
A 2x20 female header socket is soldered to the PCB at the location marked LCD DISPLAY.

Three 5-pin JST connector sockets are soldered at the locations marked LRF (J5), SWITCH (J4), and (optionally) BLUETOOTH (J9). Four 2-pin JST connector socket are soldered at the locations marked BATTERY (J8), BUZZER (J7), USB DATA (J3), and USB PWR (J2). Be sure to the note the JST socket key orientation as shown on the PCB silkscreen to install them correctly.

Li-Ion 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.

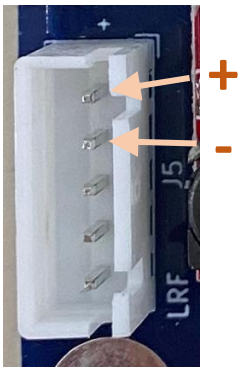
The charger board has 7 pins attached, four on the short side and three along the long side. It is then soldered directly to the PCB.



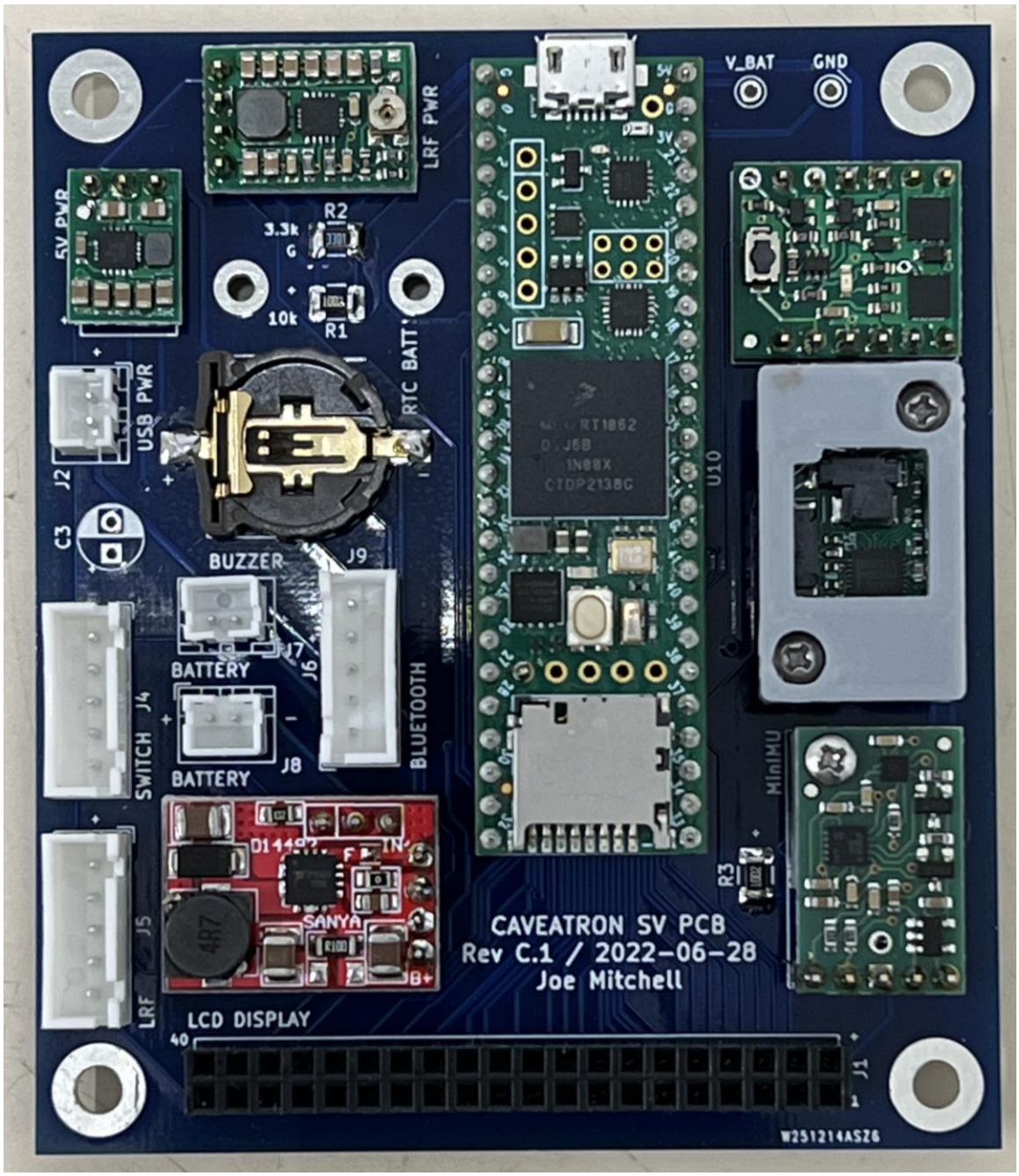
Li-ion Charger Module. The two pads indicated must be shorted together with a solder bridge or a 0-ohm resistor for it to function.

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 (J2) - the plus voltage pin (marked on the PCB with a "+", right next to the J2 label) and the minus pin right next to it. Press the small button on the Power Switch Board 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 (not including the new RTC regulator retrofit).

Main Enclosure Base Assembly

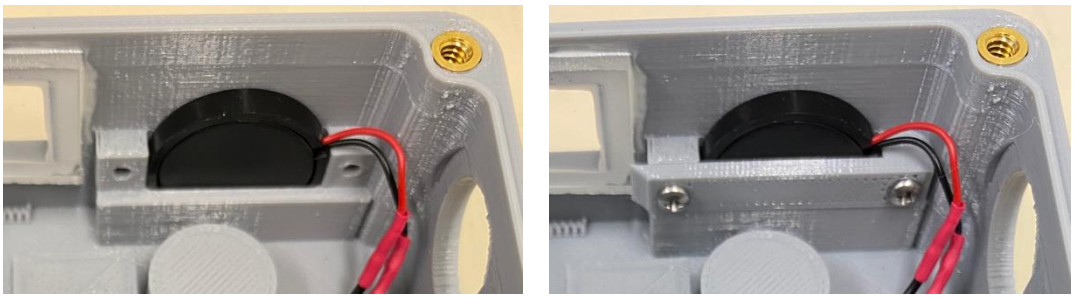
General note: When installing the thread rolling screws, it can be helpful to start the holes a little bit with the screw first before trying to install the part.

Circuit Board

Before installing the PCB, 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 ¼" thread rolling screws (one in each corner). You will need washers to prevent the screws from bottoming out in the holes which had to be shallow to avoid going too deep. 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 front wall of the enclosure. The buzzer opening faces outward toward the enclosure wall. Be sure the wires come out toward the top right of the enclosure as shown. Press it into the slot and then install the buzzer clamp. Use two 2-28 x ¼" thread rolling screws to attach it. If the piezo buzzer slides out too easily, you might need to add a piece of tape to ensure it stays in place. The end with the slight inset cutout around the hole goes toward the LRF window. Route the wires right along the front of the PCB behind the LRF mount so they can slightly slide under the corner of the PCB to hold them in place as shown in the picture on the next page.



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. When installing it, be sure the piezo buzzer wires are not getting caught by 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. Route the longer power wires in front of the LRF mount under the LRF window as shown in the photo on the next page. The USB Micro-connector part of the cable is plugged directly into the Teensy 4.1.

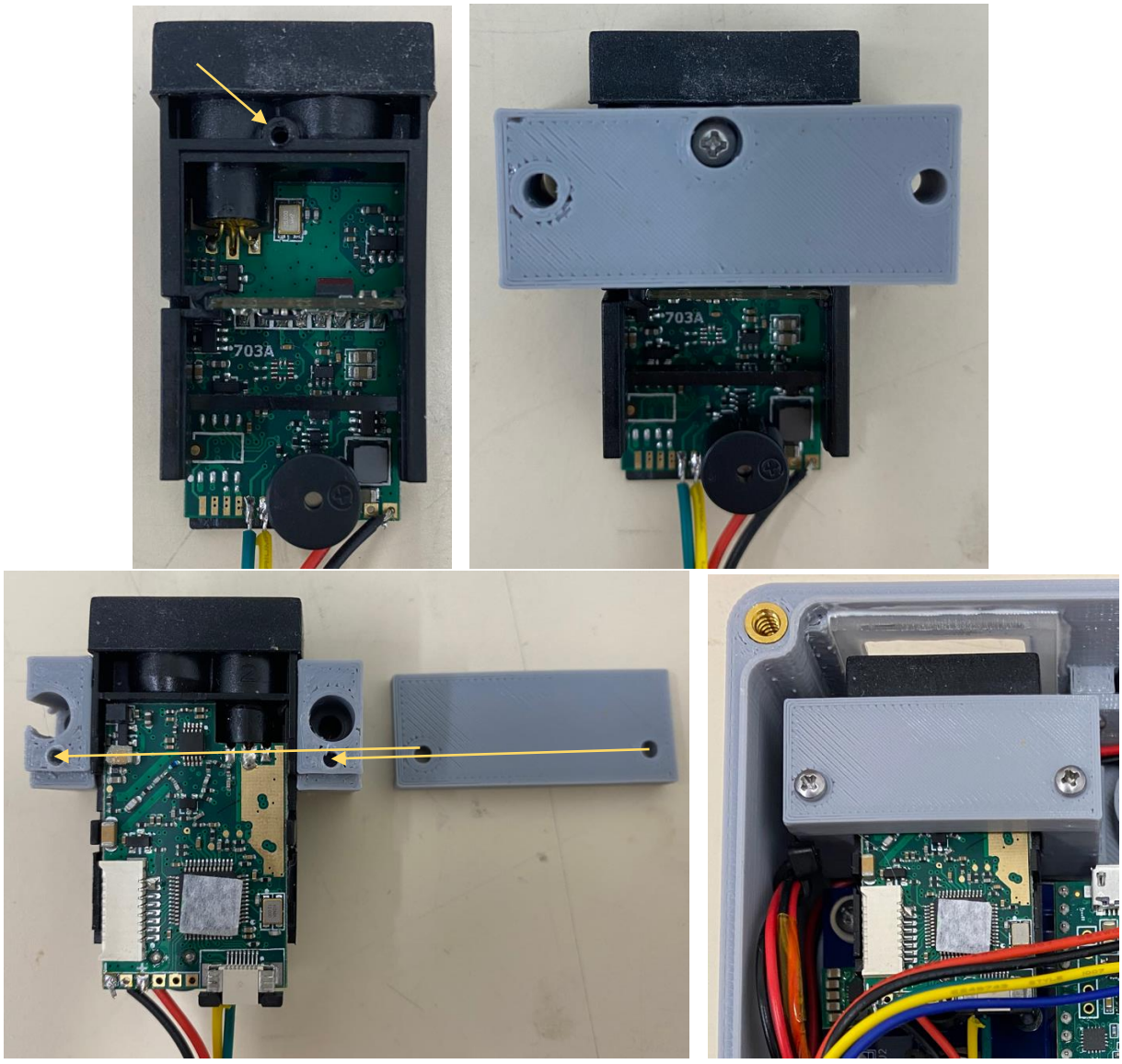
Power Switch

The power switch is inserted from the outside of the enclosure. 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. This wire harness goes across the top of the PCB to its connector as shown in the picture below.

Installation and wire routing of the power switch, USB connector, and buzzer. (The photo at upper left is from Rev A but shows the routing of the buzzer and USB power wires.)

Laser Rangefinder

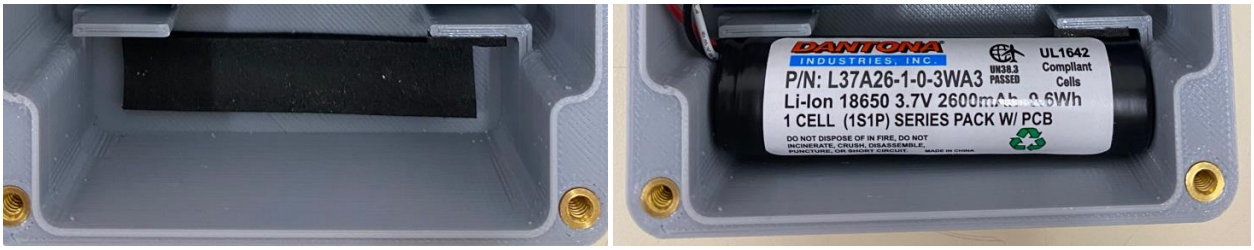
The LRF is installed in a cradle bracket that is in turn installed into the main enclosure base. When installing be sure to try to get all the parts as square to the enclosure as possible. The first step is to attach the bracket to the LRF. Look for a small hole in the front center of the LRF on one 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 ¼" thread rolling screw is used to attach it. Flip the cradle bracket over and align the two large holes with the holes on the LRF mount (visible in the picture on the previous page). Attach it with two 4-20 x ½" thread rolling screws. Finally, install the clamp on top of the cradle bracket as indicated in the photo below with two 2-28 x ¼" screws.



Installing the LRF. Attach the LRF to the bracket cradle (upper right) from the underside with a screw into the hole indicated (upper left), To install it in the enclosure, two 4-20 screws will go into the two large holes (lower left) and finally, the clamp will attach on top in the two small holes as indicated (lower left). The fully installed LRF is shown (lower right).

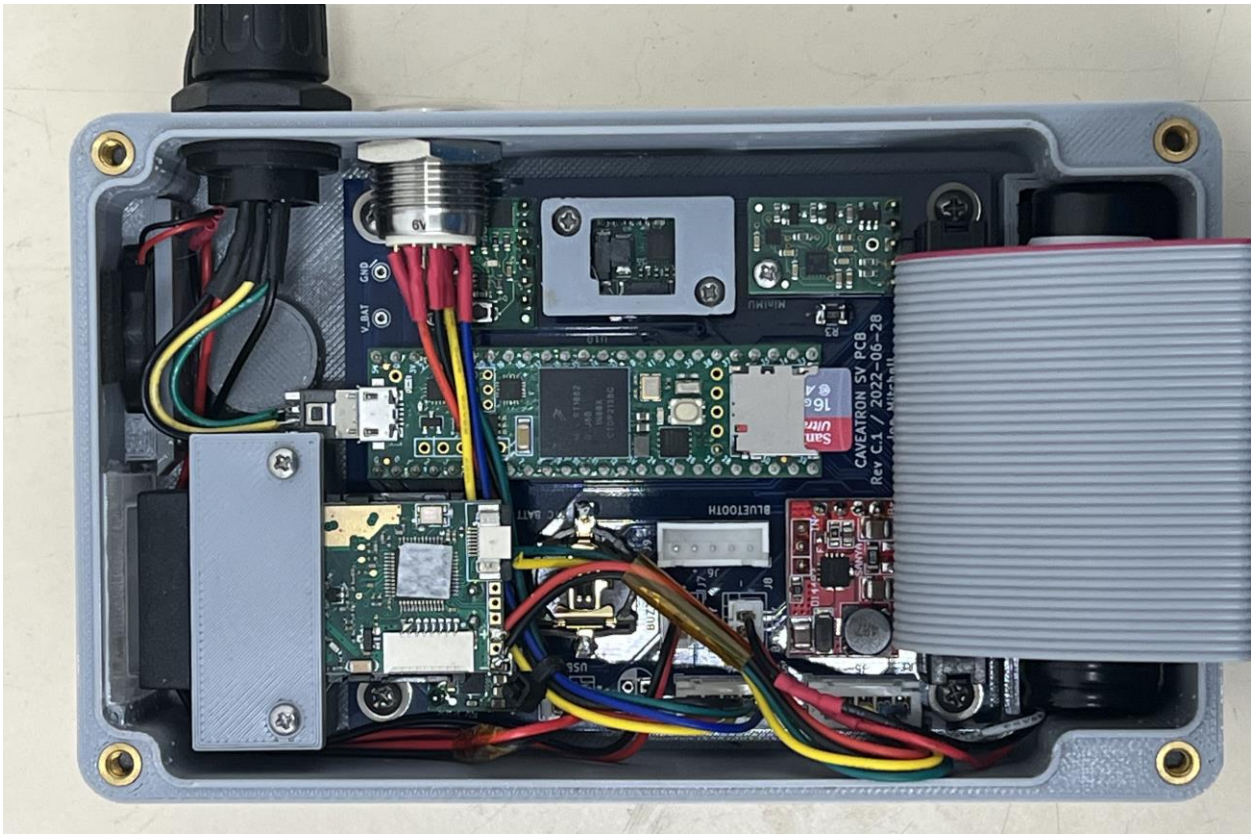
Battery

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 is placed along the bottom of the battery slot. You may also need a piece of foam on one or both of the vertical parts depending on the battery's fit. Orient the battery and insert it so that the wire harness goes into the slit on the left front corner of the battery slot (as viewed from the rear of the enclosure). The battery will be fully secured by a bracket installed in the lid.



Foam adhesive backed pads to hold the battery (left) and the battery installed (right). This battery needed an additional piece of foam installed on the right-hand vertical piece.

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.

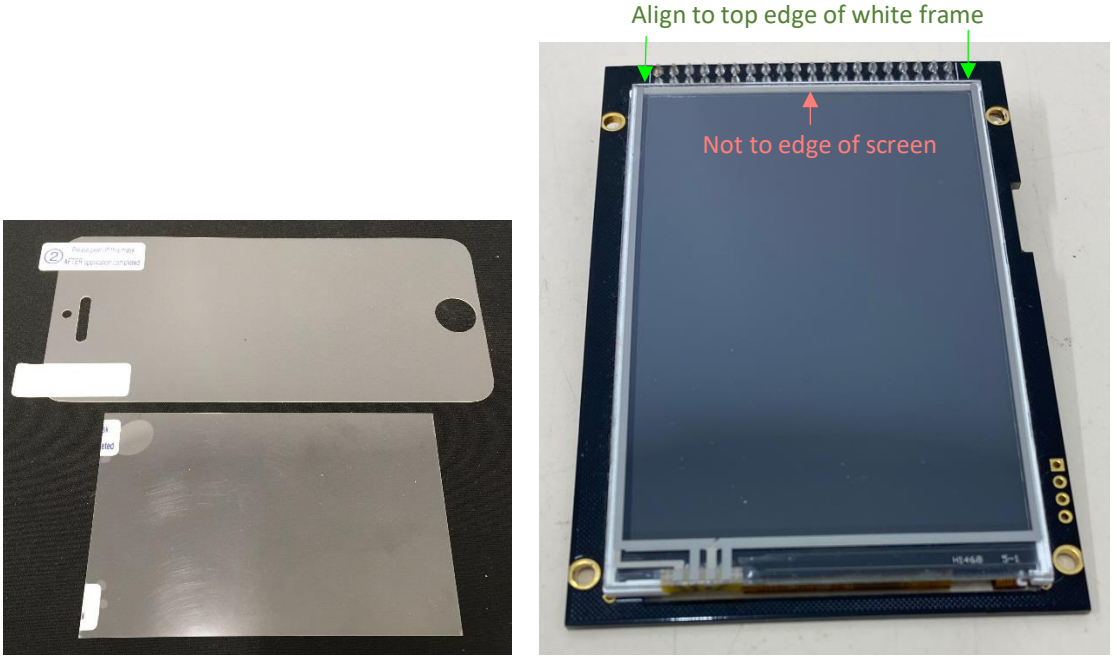
Main Enclosure Lid Assembly

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 follow length:

Screen Protector Length: 3 5/16”

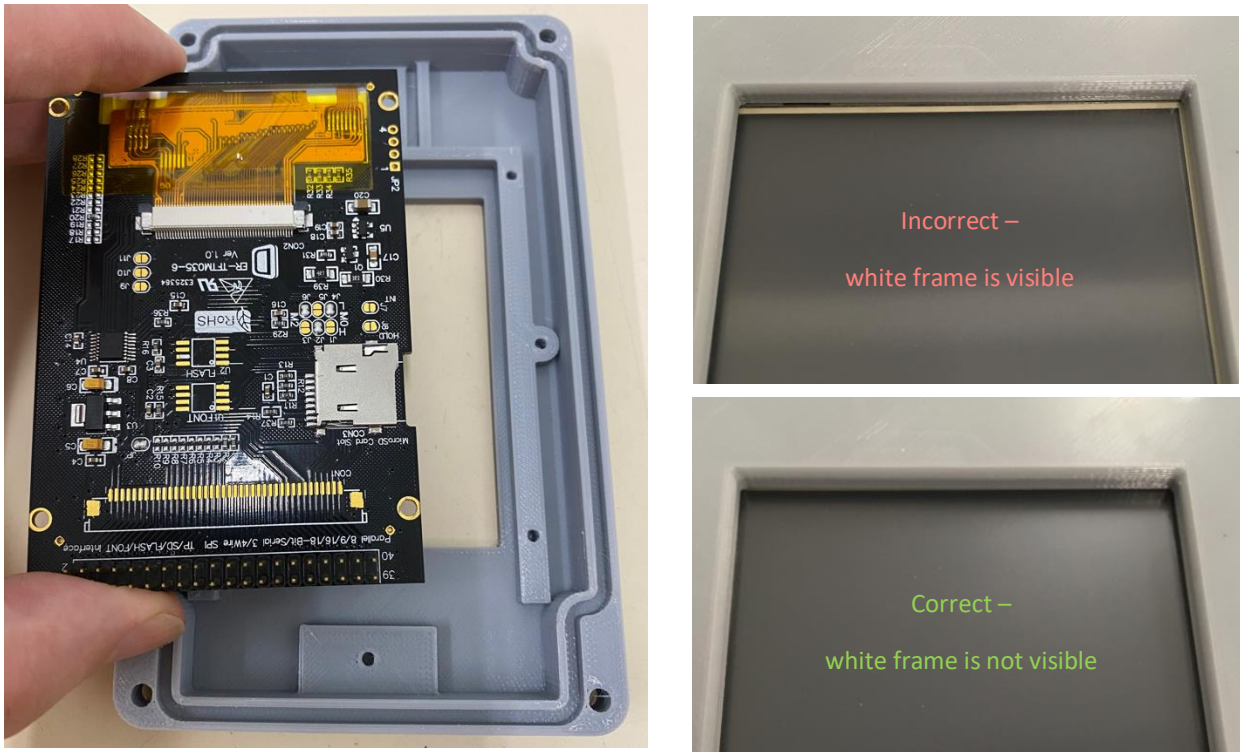
Now remove the protective film on the display. Be careful not to touch the display or get any dirt particles on the display until you get the screen protector installed. For the screen protector, peel the cover film off of screen side, being sure not to touch or get any dirt particles on the exposed 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.



Preparing the Touchscreen Display. Cutting the screen protector to length (center 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

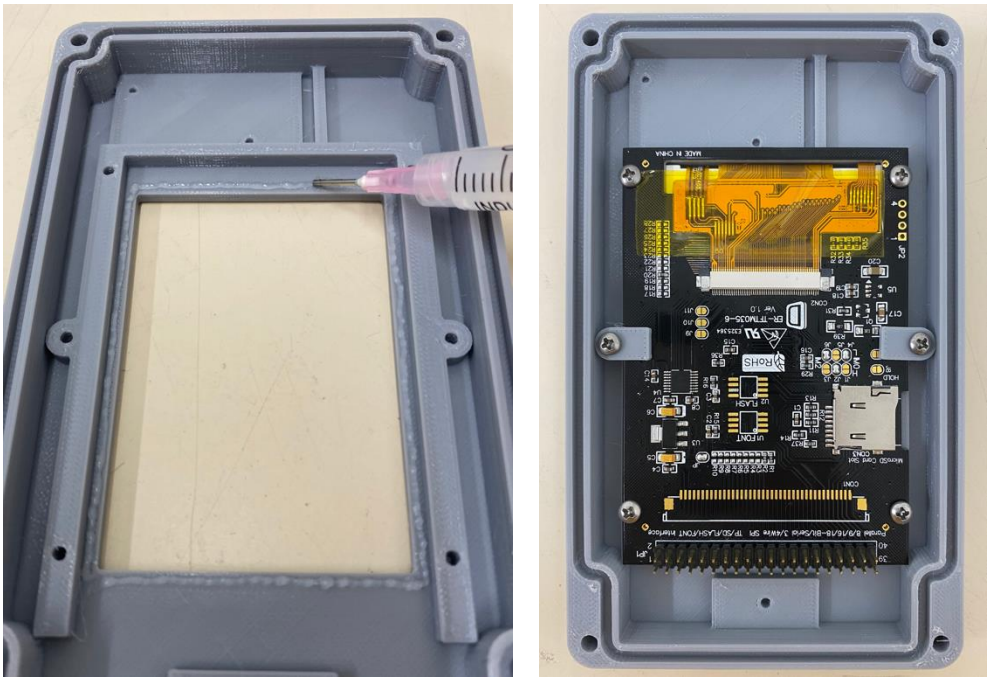
sure to get a thin, smooth bead all the way around the edge so that you get continuous coverage as shown. Don't put on too thick of a bead or it will ooze out from under the screen edges when you screw it down in the next step.



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 ¼" 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 ¼" screws into the touchscreen display clamps, as shown, so that the lip on the clip will go over the display module PCB when inserted. Install and tighten the screws. Check the topside of the screen and clean up any excess sealant. Allow the sealant to cure.

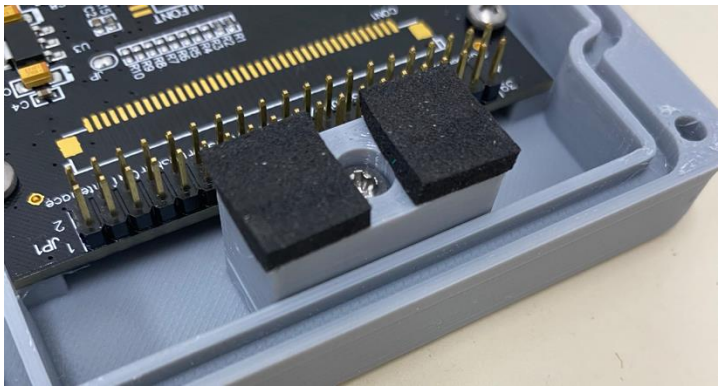
LCD clamp screw orientation



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.

Battery Clamp

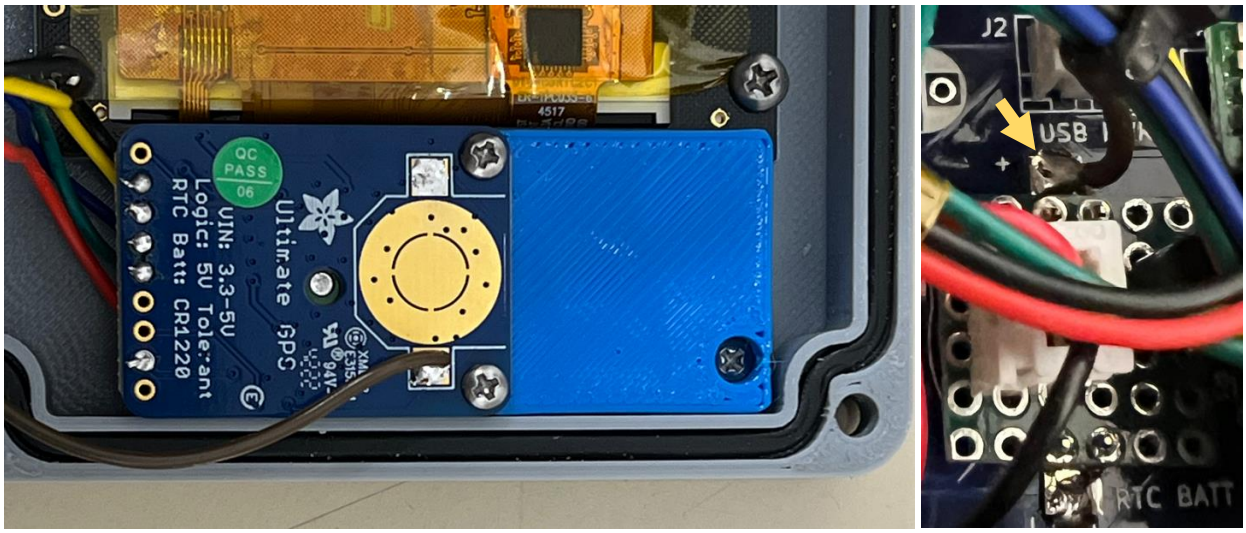
The battery clamp installs on the raised section right behind the LRF module using a single 4-20 x ½" thread rolling screw. Add pieces of adhesive backed foam as shown which will press down on the battery.



Battery clamp installed with adhesive backed foam added.

GPS Module (Optional – excludes use of Bluetooth module)

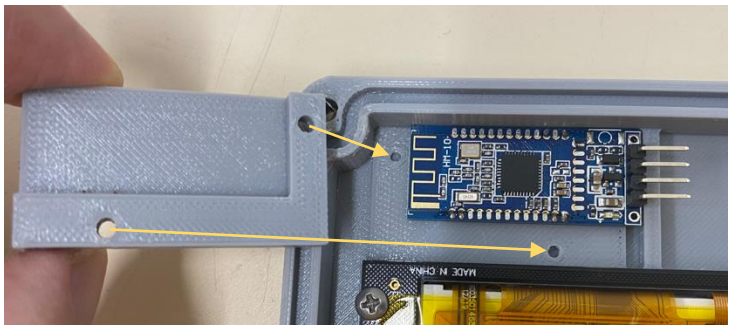
The Adafruit Ultimate GPS module is mounted on the underside of the front of the lid as shown in the photo below left. Due to the limited space, the wire harness must be soldered directly to the GPS module before installing. Be sure the wires attach on the side where the electronics are located. This connector plugs into the JRF socket on the main PCB marked "Bluetooth". The GPS bracket (shown in blue) is mounted first using two 2-28 x ¼" thread rolling screws in the holes in the lid indicated by the arrows in the photo in the Bluetooth module section below. Next, mount the GPS module upside down so the flat side is up using two 2-28 x ¼" thread rolling screws. Finally, if you want to keep the clock in the GPS module active (for faster satellite acquisition), run a wire between the backup battery pad on the module and the pad for Teensy RTC battery backup. On the GPS module, be sure to solder it to the smaller square pad, not the large round pads (with are ground). The pad closer to the front of the module is recommended as the rear one can interfere with an LRF mounting screw. The photo below right shows the connection to a Rev C board containing the RTC regulator retrofit with the attachment point for the wire indicated by the arrow (that allows it to be powered from the main battery instead of a short-life coin cell).



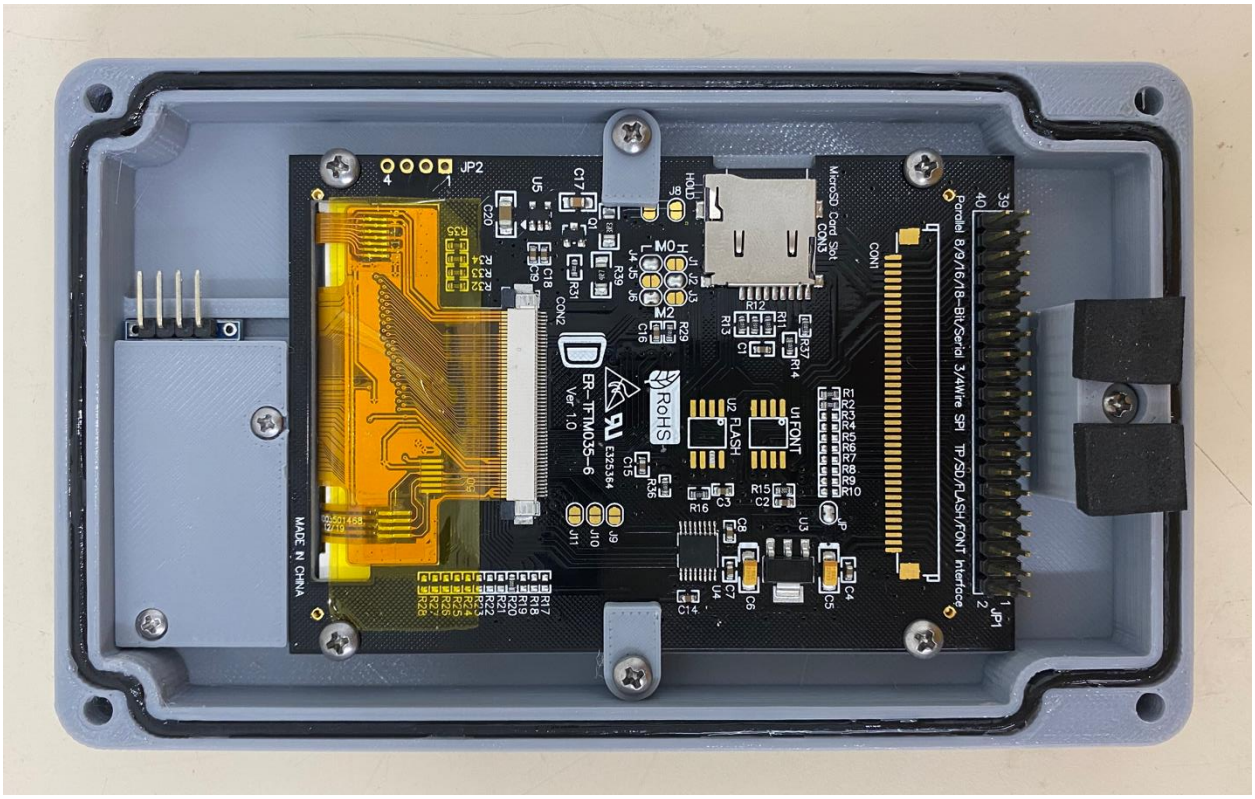
(Left) GPS module mounted on the inside of the front of the lid using the GPS bracket (in blue). Note that the electronics and 5 main wires for the wire harness are connected to the underside. These are +5V power, GND, RX, TX, and enable. This harness plugs into the "Bluetooth" JRT socket on the PCB. The GPS clock backup wire (brown) solders directly to the backup battery +power pad. (Right) The other end of the GPS clock backup wire attaches to the +power pad of the Teensy RTC backup on the main PCB.

Bluetooth Module (Optional – excludes use of GPS module)

The Bluetooth module is placed into the front part of the lid so that the underside of the pins are positioned in the slot as shown in the photo and it rests flat. Take the Bluetooth module clamp and install it so that the Bluetooth module fits inside the cutout. It is a snug fit so be sure it is fully seated. Use two 2-28 x 1/4" thread rolling screws to secure it in place.



Bluetooth module placed in position for installation. The clamp flips over from the orientation shown and the holes align with the holes in the lid as indicated by the arrows.



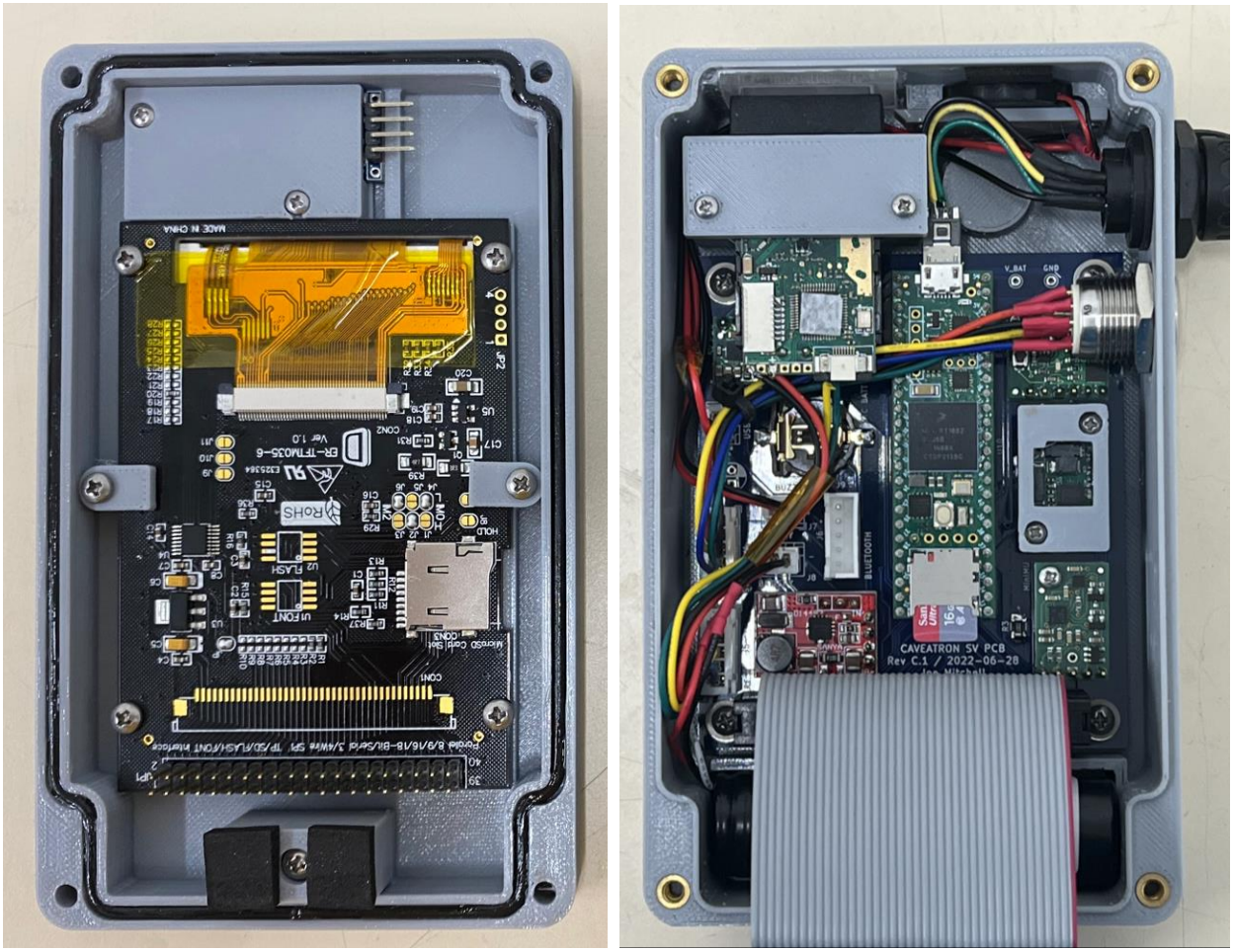
Main enclosure lid with everything installed (including a Bluetooth module) and ready for final assembly.

Final Assembly

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 SV ready for final assembly.

Connect 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.

Before attaching the lid, plug a USB cable into the external connector and plug it into 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.

Grease the O-ring on 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 1/2” flat head screws to attach it. Tighten these down.

Wrist Strap Lanyard (Optional)

A slot is provided in the right rear of the lid to install a wrist strap. Squeeze the loop end of the strap to a point and work it into the slit. Continue to press and wiggle it as it works up and around the slot until it comes back out through the other slot. Pull the other end of the strap through the small loop to secure it.

Installing the wrist strap lanyard.

Charge the Battery
Plug the USB cable in and fully charge the battery. When the ring LED on the switch turns green (or sometimes yellow) the battery is fully charged.

The Caveatron SV assembly process is now complete!

Software Installation and Setup

There are several steps remaining to prepare the Caveatron SV 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 SV 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 SV is now ready to survey caves!

Fully assembled Caveatron SV.