# Assembly/Operation Manual

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## Spectral Forest

**ME 486C- 001**

**Course Instructor:** Professor David Willy

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# Introduction

This hyperspectral VIS-NIR solar CCD spectrometer was designed by both a mechanical engineering (ME) and an electrical engineering (EE) team. It consists of two sides with one housing the optic layout, while the other is accommodating for the electrical components. The primary objective of this spectrometer is to analyze forest health by employing optical light sensing within the wavelength range of 400-1000 nm. This operation and assembly manual will go over the assembly and disassembly process of the ME portion of the design as well as provides guidance on its operation. This portion of the design includes setting up the enclosure and optics, along with incorporating a few components for the EE aspect of the design.

# Assembly

## Needed materials:

The table below outlines the necessary items and their corresponding quantities required for assembly. The part numbers are organized into subcategories to illustrate their relationships: 1 denotes the 3D printed parts, 2 represents the lens mounts, 3 signifies the optics, 4 indicates screws and inserts, 5 denotes tools, 6 encompasses miscellaneous items, and 7 covers the EE internal components.

*Table 1*

| Part # | Item | Quantity |
|---|---|---|
| 1.1 | 3D Printed Polycarbonate Enclosure | 1 |
| 1.2 | Sealing Doors | 2 |
| 2.1 | Round Lens Mount | 2 |
| 2.2 | Rectangular Lens Mount | 1 |
| 3.1 | Aspheric Lens | 2 |
| 3.2 | Diffraction Grating | 1 |
| 3.3 | Focusing Lens | 1 |
| 3.4 | Lens Cap | 1 |
| 4.1 | M4-10mm TORX Screw | 10 |
| 4.2 | M4-20mm Hex-Head Screw | 4 |
| 4.3 | #1-¼" Screws | 6 |
| 4.4 | Heat Set Insert | 11 |
| 4.5 | ¼"-20 Zinc Coated Coupling Nut | 2 |
| 4.6 | Bottom Screw Cap | 2 |
| 5.1 | 3/16” Allen key | 1 |
| 5.2 | #1 Size Philips Head Screwdriver | 1 |
| 5.3 | T10 TORX Screwdriver Bit | 1 |
| 5.4 | T20 TORX Screwdriver Bit | 1 |
| 6.1 | Neoprene O-Ring | 2 |
| 6.2 | Vents | 2 |
| 6.3 | Silica Pack | 1 |
| 6.4 | Silica Holder | 1 |
| 6.5 | Silicone | 1 |
| 6.6 | Slit Assembly | 1 |
| 7.1 | PCB | 2 |
| 7.2 | Solar Power Connector | 1 |
| 7.3 | USB Bulkhead | 1 |

# Instructions

## Optical System Installation

a. Begin by placing the 3D printed enclosure on a clean and flat surface in a dust free (minimal humidity ideal) environment.
b. Double check both heat set inserts are in place for the grating mount (both vertical and horizontal) this should have been done directly after the printing phase at the same time as the door heat sets.
c. Install the optical PCB using 2 #1x1/4" screws into the horizontally facing standoffs towards the back of the optical chamber which is on the left side (marked in red) in figure 1.
    a. Ensure the CCD chip (long rectangular one) is on the right side as seen from the perspective of figure 1.

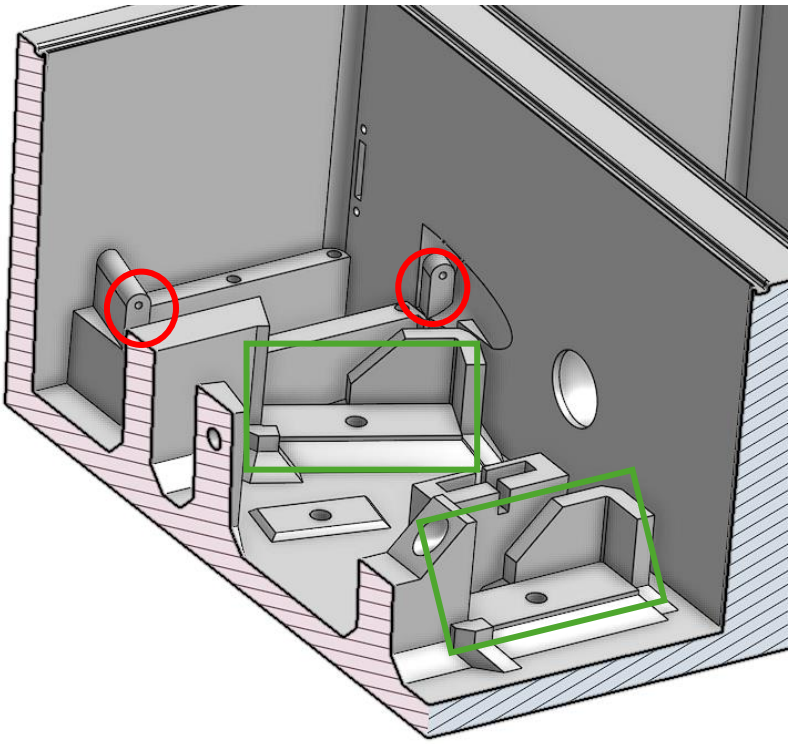


*Figure 1*

d. **Proceed with caution, with proper PPE (N95 Masks and Nitrile Gloves)**
    a. There are 3 kinds of lenses that need to be mounted. In the materials table they are referred to as aspheric lens, focusing lens, and diffraction grating. Here they will be called entrance lens, focusing lens, and grating. If you no longer have the packaging and cannot identify each lens there are ways to

tell by shape. The grating is a square (easy to isolate). The other two are more subtle but have unique shapes, the entrance lens has a greater center thickness than the focusing lens. Put simply, both circular lenses have a "flat" back and a dome-like front, the lens with a larger dome (sticks out farther) is the entrance lens. Front is the direction the dome faces, this is important.

   b. Note on lens handling: NEVER touch the center 90% of a lens or grating. This is where the light travels and even handling while wearing protective gloves will cause damage to the lens and affect the data that is collectable.

e. Now that you have PPE on, double check you have the necessary lenses, gratings, mounts, bolts, alan keys, etc…
f. Begin with mounting the first of two entrance lenses. This will go on the outside of the box in the obvious spot in line with the optic chamber.
   a. This is done by putting a thin but consistent layer of RTV then slotting the lens into place. Be careful not to spread RTV anywhere including your gloves (replace if needed).
g. Outside of the enclosure, place the focusing lens into one of the vertical drive mounts. This one will go closest to the CCD chip. Easiest if mount is on its back facing up so the lens can just be dropped in. Focusing lens should be facing towards the entrance lens and grating. Once, in place use a 0.05" alan key to tighten the set screw down enough to keep the lens snug but not much more (do not over tighten). Place the mount in its designed holder (will be snug but it will fit) then tight down the bottom screw (M4x20 hex head) from the outside and the side mounted screw from inside.
   a. Great! First one done. Now is a good time to check that nothing is loose or moving.
h. Next, we will do the mount only for the grating. This is a multi-step process. Prepare the grating mount by removing the top clamp (two screws) and unscrewing the upright support for the clamp (only one needs to and can be removed). You should have three separate parts now. Place the lower part of the mount (the majority) into place and tighten lower and side set screws. Do this evenly while alternating to ensure it gets set evenly and in place. Once tightened, screw in the upright. We will continue this later.
i. Now we move onto the second entrance lens. Repeat the same loading procedure for the focusing lens. The only difference is the front of the lens "dome side" will be facing away from the entrance lens. See Figure 2. Note: side width is different so what makes the lens "snug" may be different.

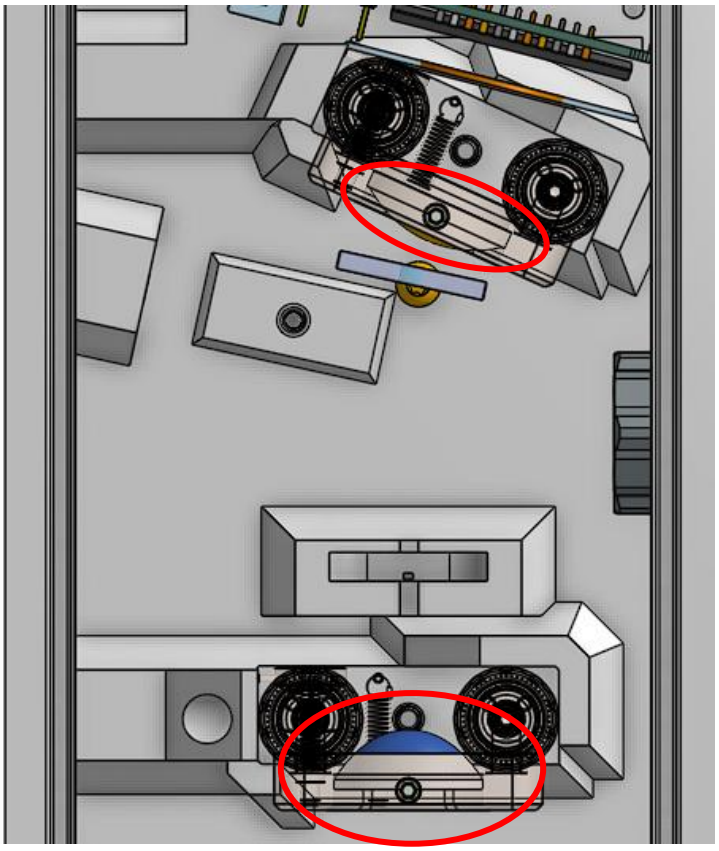
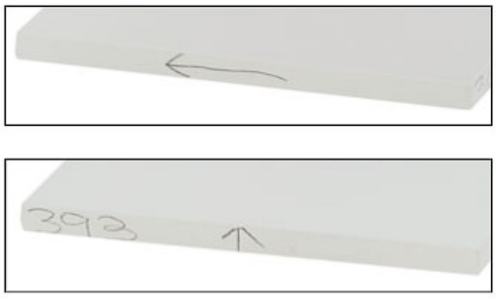


*Figure 2*

j. Now all we have left is the second half of the grating and the slit.
    a. For the grating, we will carefully place the grating in keeping in mind the orientation (front vs back and top vs side vs bottom). Check out figure 3 for guidance.



Click to Enlarge
**Top Image:** On one edge of the grating, an arrow parallel to the grating's surface indicates the blaze direction.
**Bottom Image:** On the opposite edge of the grating, an arrow perpendicular to the grating's surface indicates the transmission direction.

*Figure 3*

k. Place the grating on ONLY the rubberized portion of the mount. Yes, it will “hang off” this is normal. In figure 3 this is shown in light grey. Place the clamp back onto the upright poles and press down firmly enough. Tighten the clamp screws.

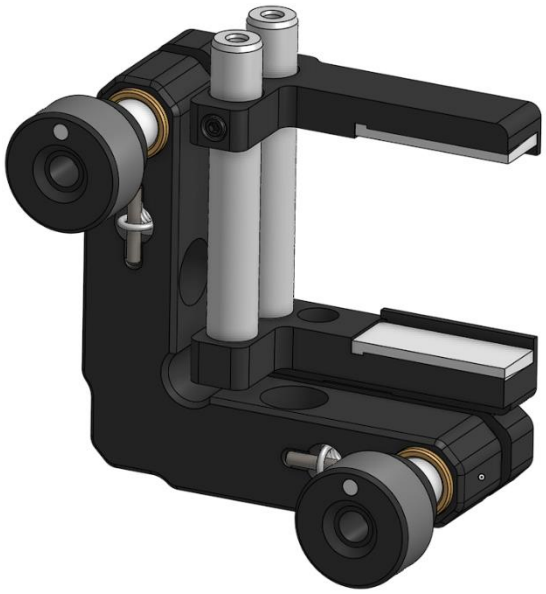


*Figure 4*

l. Now that grating and all lenses are in place, firmly push the aluminum slit into its 3D printed holster. Make sure the slit is vertically orientated.

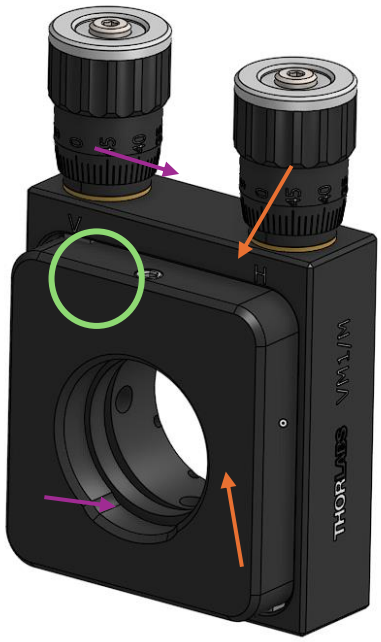



*Figure 5*

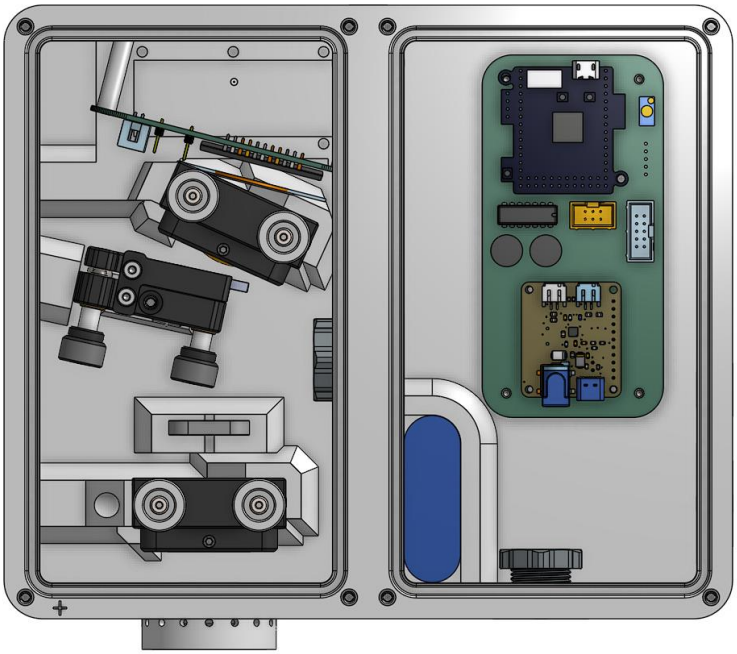


*Figure 6*

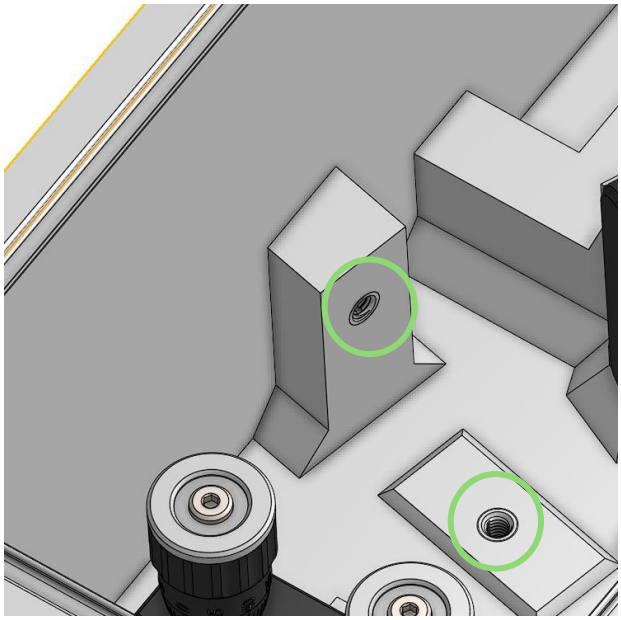


*Figure 7*

NOTES: in the above figures we can see some key spots. Figure 5 is a CAD drawing of a vertical drive mount. Figure 6 is a top view of the optic system. In pink are the locations for the side mount set screws. Orange is the direction of the lenses in their respective locations. And green shows where a heat set insert will be and needs to be used. Figure 7 also shows the same green, this is for the grating mount.

## Other Installation Processes

a. Install the heat set inserts into the top corners of the enclosure to hold screws for doors. To do this lightly push the tapered end of the insert into the hole until is clicks in and it should hold itself upright. Using the heat set insert tool (shown below) and the M4 attachment, turn the tool on by holding the red button and setting it to 300C, press the tip into the heat set insert and wait for it to begin sinking into the plastic, hold firm until it is flush with the surface.
b. Repeat for all 8 spots on the top surface of the enclosure
c. One additional heat set insert is need and is used to hold the battery in place. Install the heat set insert and take an M4x10 TORX and screw it in after the batter is installed

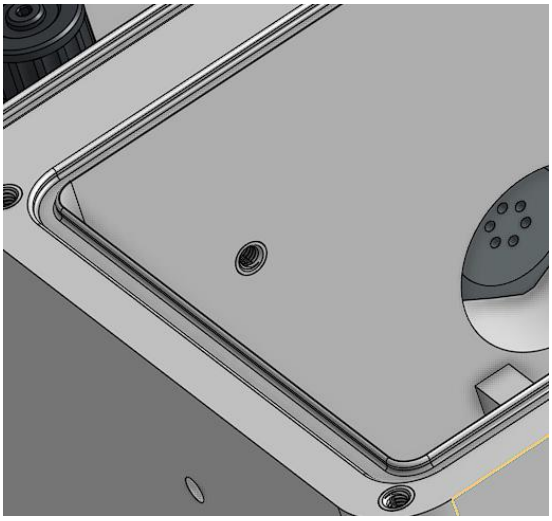


*Figure 8*

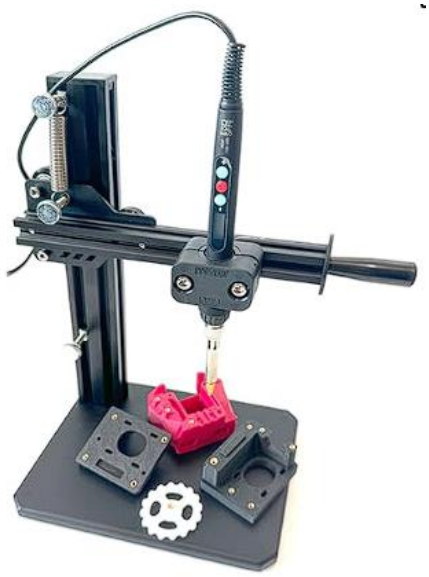


*Figure 9*

d. Take the 2 ¼”x20coupling nuts and heat set them into the bottom and rear of the device. Switch to the M6 sized attachment and insert it into the coupling nut that is standing straight up out of the box and wait for it to slowly sink into the wall. Detaching the heat set insert soldering iron will be helpful.
e. Install neoprene O-rings in the grooves in the top surface of the enclosure, using a toothpick and silicone, apply silicone to the entire inner edge of the O-ring groove. Then place the O-ring in the groove by holding 2 edges while forcing the last 2 into place. Hold down for 30 seconds to allow the O-ring to set with the silicone.
f. Install vents in the inside and outer wall of the enclosure, shown below.

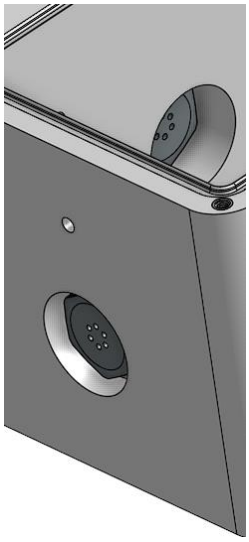


*Figure 10*

g. Install the silica pouch and holder in the shown location behind the PCB in the optics chamber. The silica pouch will be placed below the red holder shown.

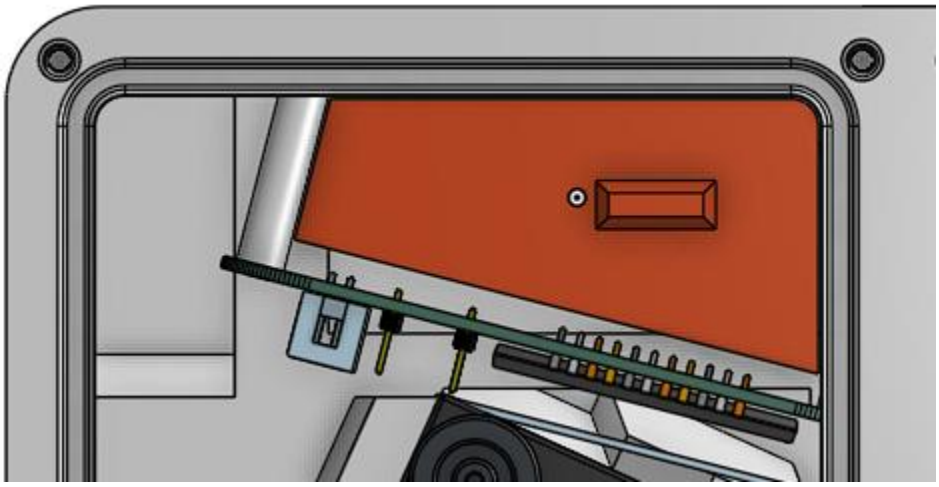


*Figure 11*

h. Attach the doors to the enclosure using the M4x10mm TORX screws
i. Place the lens cap on lens 1 that is exposed
j. Insert the bottom screw caps with a touch of silicone

# EE component installation

a. Using 4 #1x1/4” tri-lobe screws install the main PCB on the electronics chamber. Reference the figure below (green circles)
b. Install the battery and connect it to the correct port of not already (blue circle).

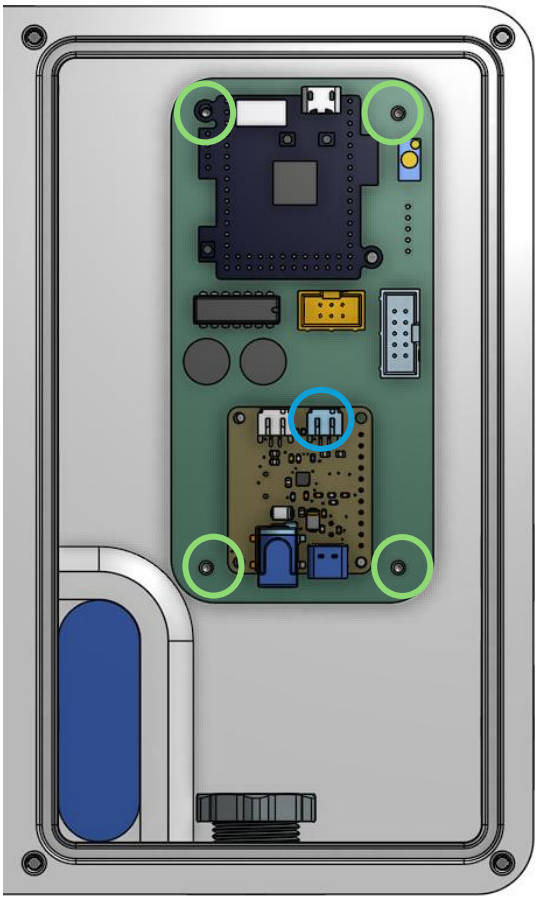


*Figure 12*

c. The right side of the device holds the two EE connectors the left one is the USB bulkhead mount which is to be installed with the retaining ring on the outside and the O-ring on the inside
d. The right side of the below picture is for the solar connector and it should have the black part facing out and the retaining ring on the inside.

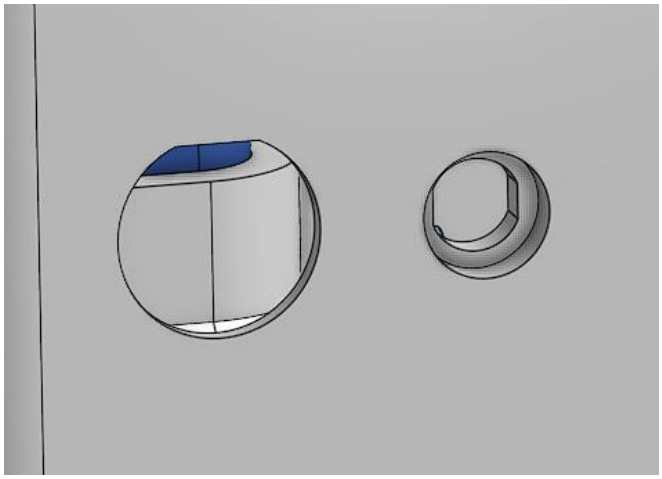


*Figure 13*

e. The two small holes towards the top of the picture are for the photo sensor (left) and the indicator LED (right). Refer to the EE manual for wire connections.
f. Once wired up, slide the photo sensor in to the hole on the left with a dab of silicone underneath
g. Repeat with the LED on the right

*Figure 14*

## Disassembly

a. Unscrew and remove the bottom screw caps.
b. Remove the lens cap from the focusing lens.
c. Unscrew and detach the doors from the enclosure.
d. Remove any screws securing the optical components and mounts.
e. Take out the optical components, mounts, and any other installed parts from the enclosure.

## Operation

The EE team has designed the electrical components of the device and thoroughly outlined its operation and activation process in their comprehensive operation/assembly manual. With the device in operation, it should function when being placed within a forest environment or mounted to a drone, ready to record spectral data upon the removal of its lens cap.

## Maintenance Instructions

- Clean the exterior of the spectrometer with a wet rag after each use in the field to remove any dirt or debris.
- Regularly check for any signs of damage or wear on the enclosure and optical components.
- Ensure all caps and plugs are in place while not in use to prevent unnecessary dust or moisture ingress.
- Once a month, open the enclosure in an indoor and sanitary setting while wearing appropriate PPE to inspect for any dirt or water ingress on the interior components.

## Troubleshooting

- Check if the lens cap is removed
- In case the device is not functioning properly, ensure you have all the proper PPE and begin inspecting internal components for potential damage or ingress.
- Ensure the lenses are installed in the correct orientation
- Check ribbon cable connection
- If all is up to code, disassemble to view components in more detail. Any damage to the lenses can result in a loss of light and may require replacement.

- Follow the troubleshooting guide provided by the EE portion of the design for electrical component issues.