Design and Construction of the Power System Housing for the Space Weather UnderGround's Magnetometer

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for
Dr. Charles Smith
https://eos.unh.edu/space-science-center/outreach/space-weather-underground

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Overview:

Although the main magnetometer is placed in a PVC tube underground to stabilize it from temperature variations that can alter the magnetometer's calibration, the remote deployment of the magnetometer relies on a solar-powered battery system. These support systems must be housed in a durable weatherproof enclosure. The goal of this paper is to document the construction of such an enclosure (A.K.A. "the doghouse")

Requirements for the Doghouse:

As the Space Weather UnderGround (SWUG) is fundamentally a citizen science program aimed at involving students from local schools, the primary goal of the doghouse design project was to produce a housing that could be manufactured locally at minimal cost with basic construction tools and skills in less than a weekend. Participating in the building of the doghouse would increase the range of students and parents that would enjoy contributing to the SWUG project.

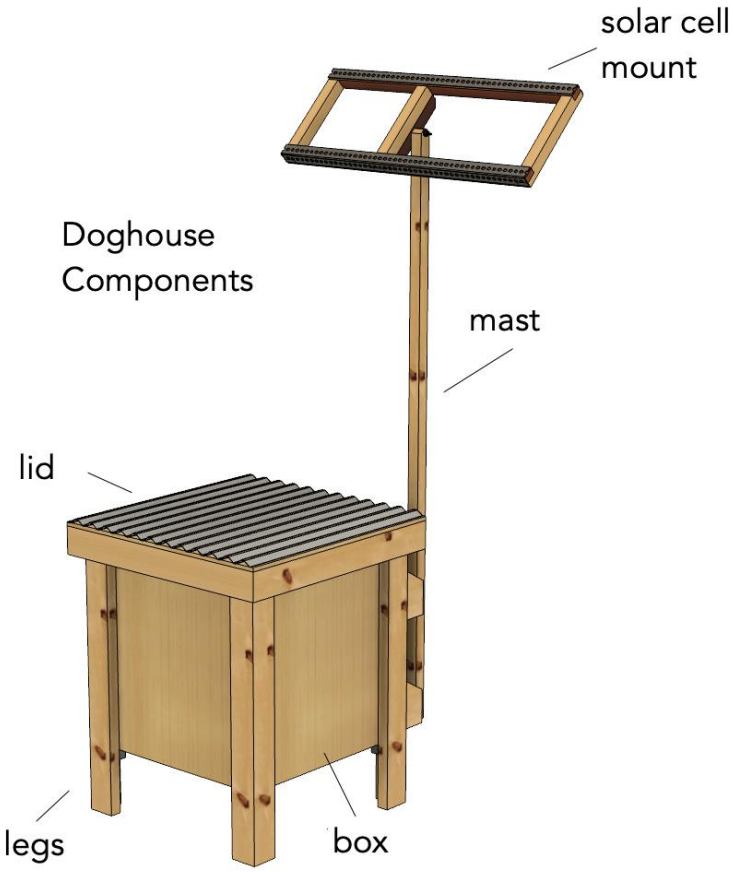
Design:

The design considerations for the doghouse included:

- Weather proofing
- Insulation (magnetic and thermal)
- Protection from critters and insects (and curious people).
- Stability from wind and snow
- Visibility
- Antenna alignment
- Solar Cell adjustment
- Inexpensive common materials sourced from home improvement stores

The current design has survived one year through winter storms without issue.

Design Layout



Tools:

Common woodworking tools were used for the construction. Of course, adult supervision and safety protocols must be followed. Seek experienced help as needed.

Hand tools: hammer, handsaw, pliers, screwdriver, square, clamps, straight edge, measuring tape, caulk gun.

Power tools: circular saw, powered screwdriver

Nice-to-have tools: table saw, chop saw, pneumatic nail gun.

Materials:

Substitutions can (and should!) be made to save costs. It should be noted that the materials for the first two prototypes were purchased at the height of COVID when material costs were exorbitant. Current costs should be lower.

Item	Quantity	~Cost	Part
Pine 2”x4”x8’	6	$60	Frame
Tuftex 5-Pack Cross Link Polyethylene Solid Roof Panel Closure Strips	1	$11	lid
DAP Alex Fast Dry 10.1-oz White Paintable Latex Caulk	2	$9	Sealant, glue
LIQUID NAILS LN-903	2	$8	glue
Tuftex PolyCarb 2.16-ft x 8-ft Corrugated Smoke Polycarbonate Plastic Roof Panel	1	$27	Lid
Johns Manville R- 2.7, 0.5-in x 4-ft x 8-ft AP Foil Faced Polyisocyanurate Board Insulation	1	$20	Box and top insulation
Plytanium Natural/Rough Sawn Syp Plywood Lap Siding (0.3437-in x 48-in x 96-in)	1	$37	Box sides and bottom
1-1/4 in. x 18-Gauge x 72 in. Zinc-Plated Slotted Angle	1	$18	Solar cell mount
1/2-in x 3-in Zinc-plated Coarse Thread Interior Carriage Bolt (1), two washers, two nuts	1	$1	Solar cell mount
Weatherproof decking screws 3.25”	~10-30	$10	Frame, lid, mast
Weatherproof latex paint (white)	1	0	Frame, lid, box
Common 4-in x 4-in Powder-coated Wood To Wood Post Spike	1	$33	legs
	Total	$234.00	

Although it is ideal if the doghouse is built locally close to the school, perhaps in wood shop if the school has that resource, the SWUG program is prepared to offset the cost of materials.

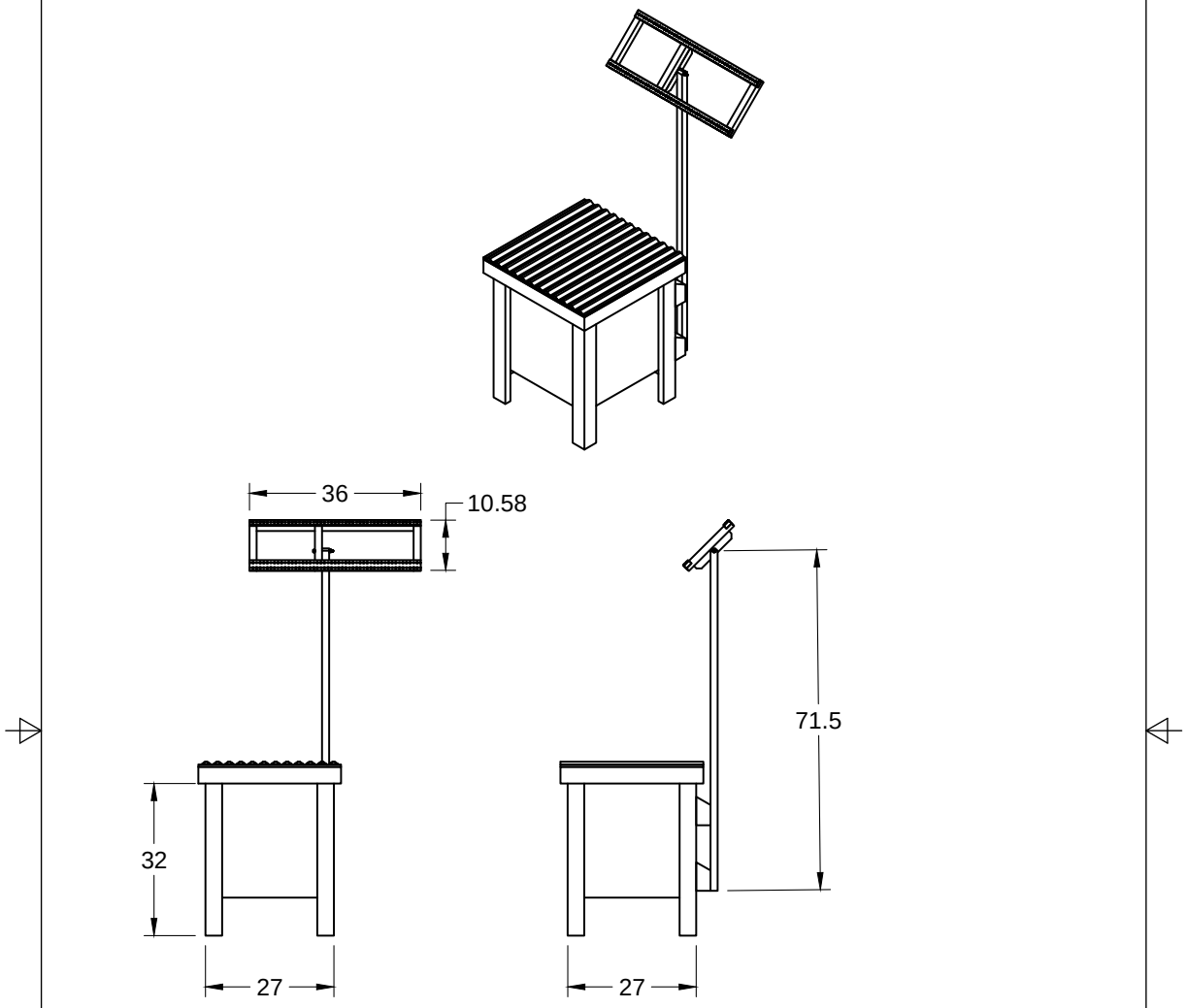
Build

The build is as straight forward as it looks.

- Four legs are attached with exterior grade plywood to form a box. A floor is inserted.
- The inside of the box is lined with foil-backed foam board for insulation.
- A removeable shelf holds the battery chargers above the battery box.
- A lid slides over the top of the box.
- The lid is topped with corrugated plastic roofing.
- A mast is attached by a pivot point to a wooden frame to hold the solar cells. The solar cells are bolted to the angle brackets.
- All joints and edges are thoroughly caulked before painting.
- A screw through the side of the lid into the box provides a simple locking system for the lid.
- The mailbox post secures one leg of the doghouse to the ground.
- The LORA antenna is secured to the mast.
- A hole is drilled for the cables running into the box and caulked.

Measurements:

- Build measurements can be approximate. It is recommended that the box size not be less than specified or the battery boxes may not fit.
- When building the solar cell mount it is recommended that it be custom fitted to the solar cells provided. These may well vary from the dimension specified as the source may change.



dimensions in inches

PROJECT

Magnetometer Battery Enclosure

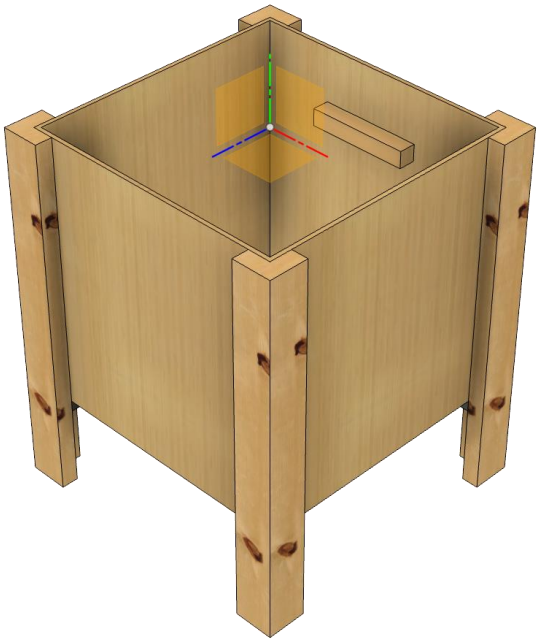
TITLE

DogHouse

APPROVED	SIZE	CODE	DWG NO	REV
CHECKED	A			5
DRAWN Scott Goelzer 9/6/21	SCALE 1:30	WEIGHT		SHEET 1/1

Assembly Procedures:

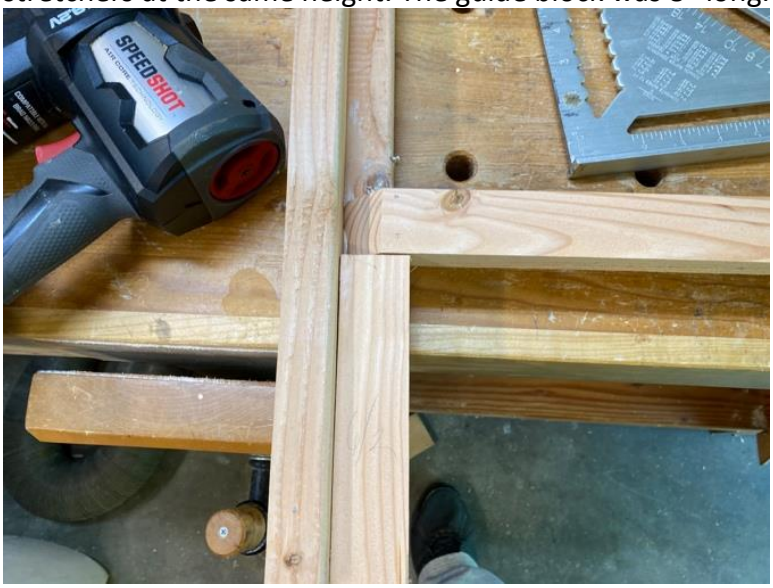
Legs and Box

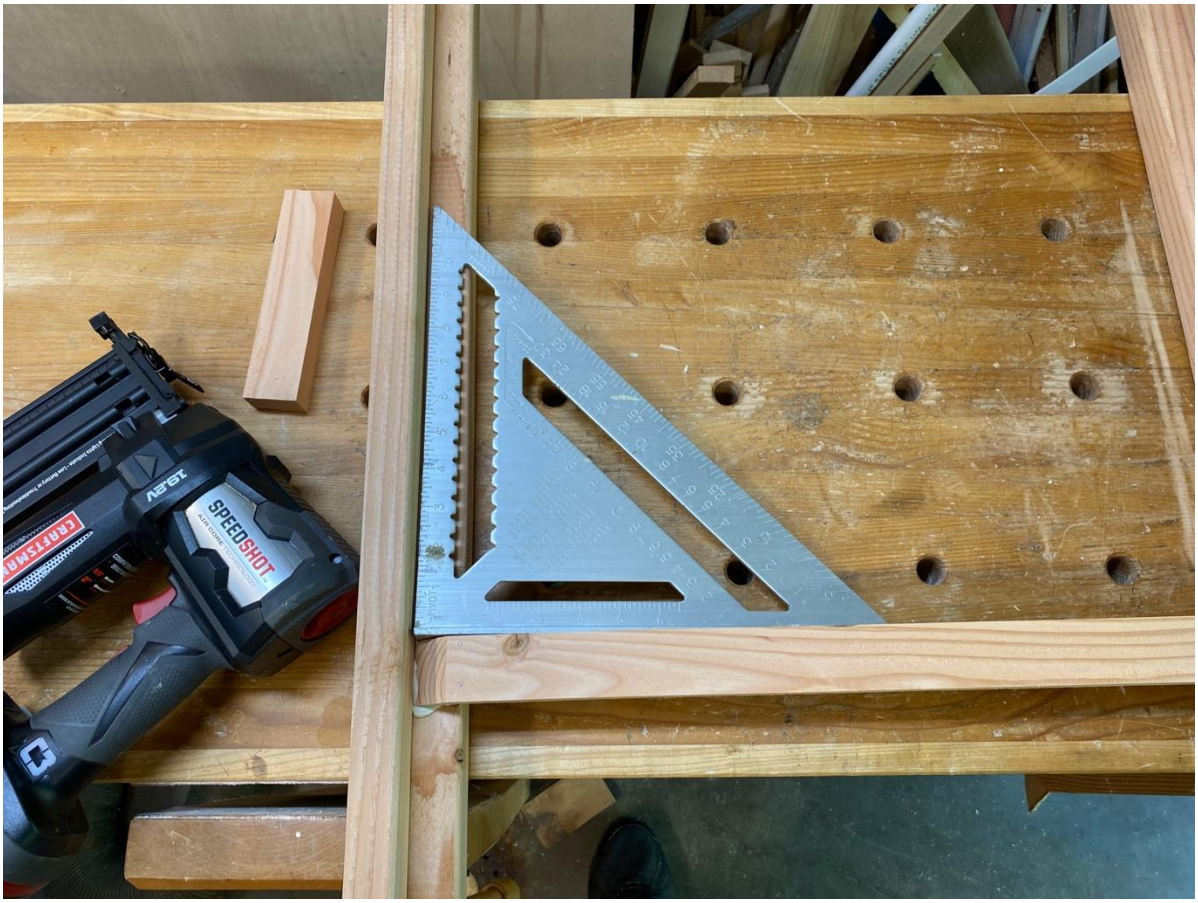


1. Four legs were made by ripping 1.0” from pine 2”x4” into 32” lengths. The sections were screwed and glued to form legs. *This is not fine furniture; close is good enough*.

2. Four stretchers were made from 1”x1.5”x 25” square pine stock ripped from studs and mitered to 45°. Point to point length is 25”

3. Glue and nail stretchers to legs. A scrap guide block is shown to keep all of the stretchers at the same height. The guide block was 8” long.




SPEEDSHOT

4. Cut the exterior plywood panels to fit inside the frames. It is likely by now that the build dimensions will have deviated from spec by a small amount. Nail (or screw) and glue the panels to the legs.

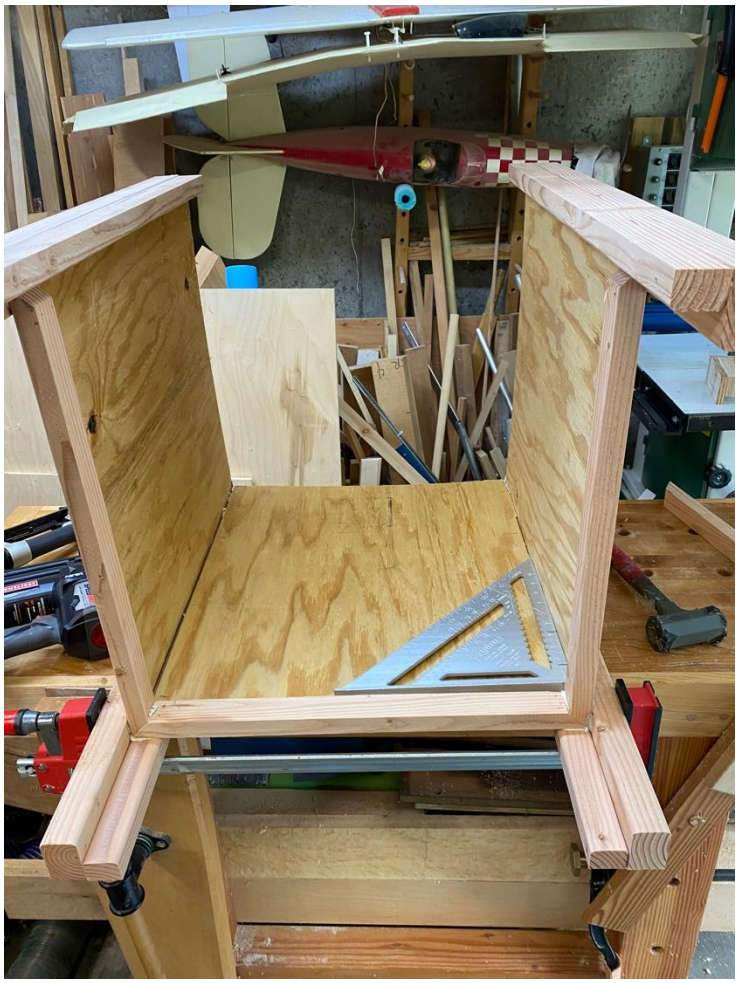

CRAFTSMAN
AEG
SPEEDSHOT

5. Build a matching leg-panel assembly for the opposite side.

The bottom stretchers will form the support for the floor.

6. Use one of the two remaining stretchers to connect the two panels together. Clamps or an assistant help hold this all together.

7. Cut to fit another plywood panel to the side panel. Glue and screw. Exterior side out of course



8. Install the remaining stretcher and side panel.

The box strength now comes from a stressed-skin structure.

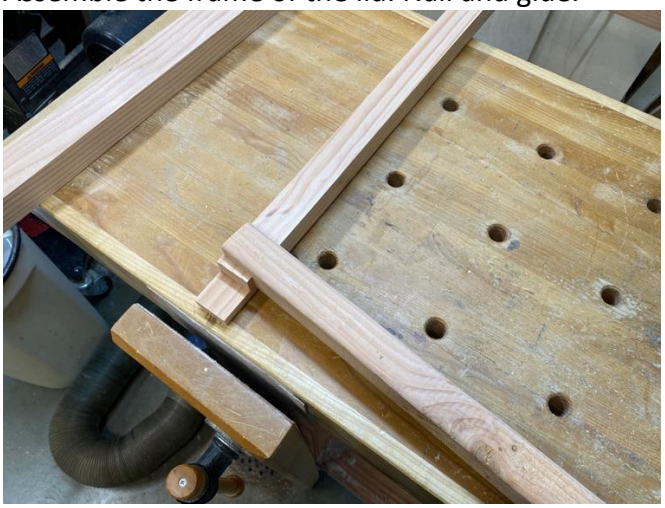
9. Cut and fit a panel for the bottom. Glue and nail it to the bottom. Exterior side downwards.

The carcass is mostly complete.

Constructing the lid

10. The lid will drop down over the legs outside of the box. Measure the exterior dimensions of legs from outside point to outside point. Ideally, they should be square, but it is acceptable if they are not. This will create a weathertight seal over the box and a drip edge to allow the lid to shed water. Although simple butt joints could be used, half – lap joints are far stronger and easier to assemble. Cut these from 1.5” square stock ripped from studs. Leave an extra 0.25” on the inside dimension of the lid to allow the lid to just slip over the frame.

11. Assemble the frame of the lid. Nail and glue.



12. Cut to fit a section of exterior plywood to the top. Glue and nail.

13. The lid will be painted, but it will take the brunt of the weather. A section of corrugated roofing was screwed to the top after it was painted. Corrugated foam inserts were added to improve the weathertight seal and provide a better drip edge. Very cheap insurance.

14. Roofing screws were used to secure the roofing to the lid.

15. The inside of the box and lid was lined with metal backed foam insulation. Cut to fit the panels and glue to the bottom and sides. Cut the foam panels such that they are short of the top of the box by the thickness of the foam panel, approximately 1 inch.

16. Cut and fit a panel to drop into the recess left by the installation of previous foam panels.

Not shown: use duct tape to form a small pull-tab that attaches to the center of inset foam panel.

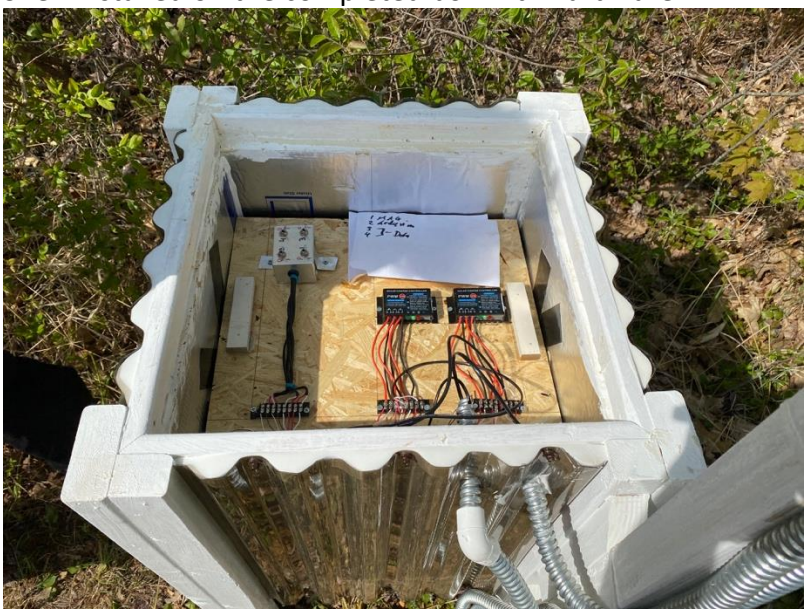
17. Remove the foam lid and apply a bead of silicone sealant around the perimeter of the lid. Allow it dry without the foam lid in place. This bead will help seal the inner box.

Use scrap wood to smear the bead out along the perimeter.

When the foam lid is in place, there will be good thermal seal inside the box.

18. The battery charges and main switch assembly will ride on plywood board above the battery box. Create two cleats two support this ‘shelf’. The shelf should be about 6” below the top of the box

Shelf installed on the completed box with hardware:



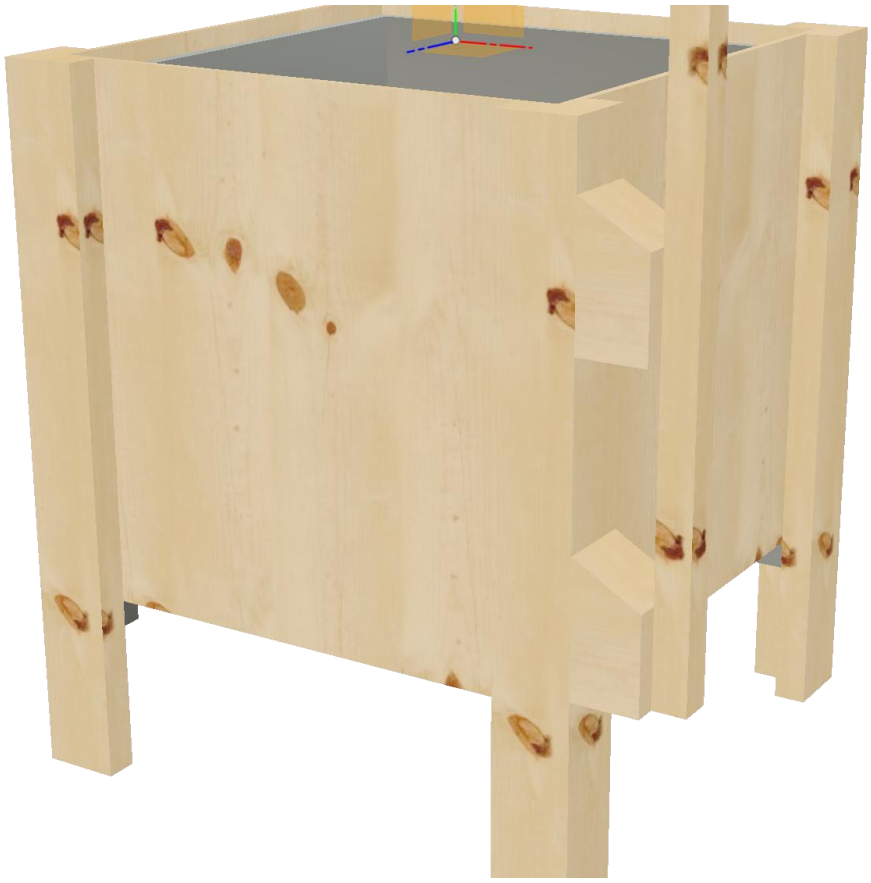
Shelf with switch harness, chargers, and battery boxes.

In the image above, the first prototype used the corrugated panels to weatherproof the outside. The second prototype used exterior grade plywood (greater cost, but simpler construction. Both methods have proven successful.

Installation of the Mast

The mast will be screwed and glued to the box.

19. Use scrap wood to create enough offset for the lid. The offset blocks were beveled to shed water better.



20. The mast is made from 1.5” square stock and is 6 ft long. Glue and screw it to the offset blocks. Drill a 7/16” hole at the top to receive the carriage bolt.

Offset blocks were simplified on prototype #2

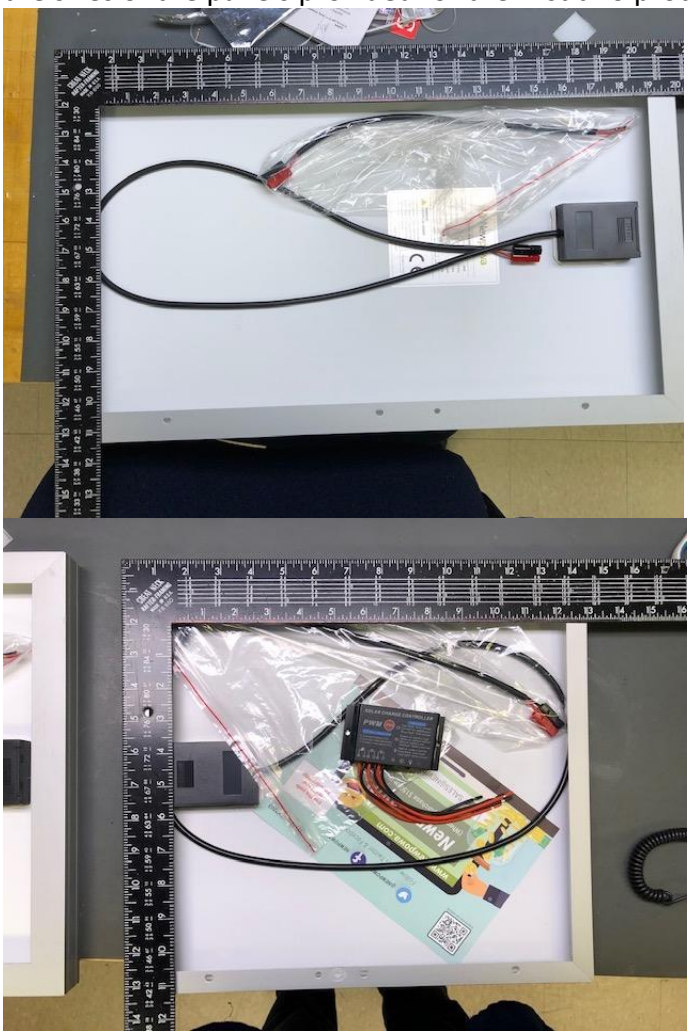
The Solar Panel Mount

The solar panels are the most difficult part of the build. The mount must:

a. Hold both panels at an optimum angle,
b. Be strong enough to survive wind,
c. Keep the weather from the back of the panels,
d. Attach the panels to the frame without obstructing the view.

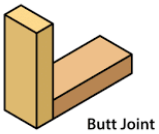
There are two solar panels that supply two batteries. The reason for this is to prevent electrical ground-loops between the radio system and the magnetometer system.

It is entirely possible that the panel sizes could change in the future if sources become unavailable. The design of the mount for the panels can be customized as needed. Below are the sizes of the panels provided for the first two prototype doghouses:

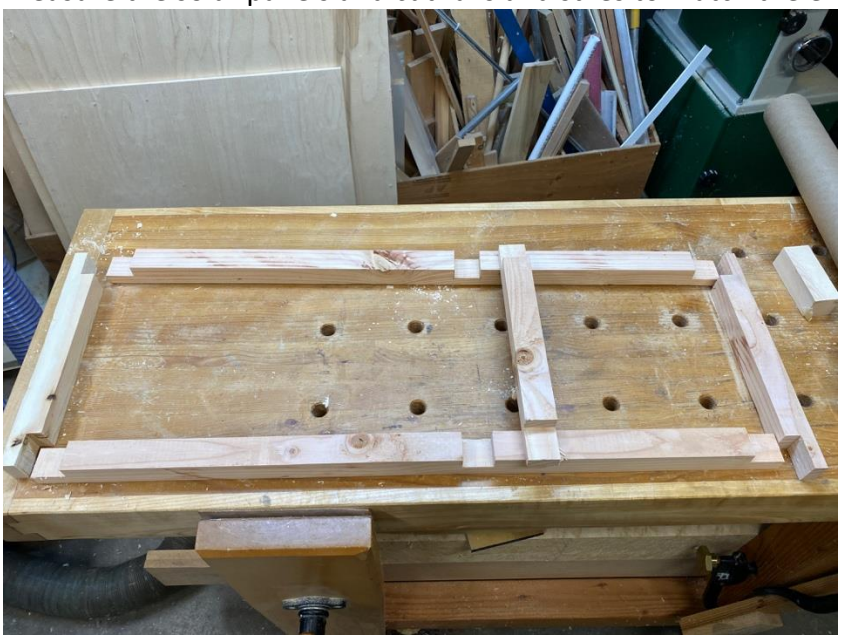


The panels were of different widths, but the same heights and thicknesses

Again, the frame was cut from 1.5” square pine studs. Half-lap joinery was used for strength. It should be noted that a glued and nail butt-joint version was made to save time and effort. It failed and was replaced with the half-lap version. It might be possible to reinforce a butt-joint frame with metal brackets at greater expense.



21. Measure the solar panels and cut rails and stiles to match the exterior dimensions.



The center stile should be positioned so that the joint between the two solar panels is positioned in the middle of the stile.

22. Create a center brace to attach the mast to the frame from a scrap of 1.5” square stock. Drill a 7/16” hole to receive the carriage bolt through the brace before it is attached. Glue and screw (wood screws) to the center stile. This connection must be very strong.

23. Reinforce the half-lap corner joints with wood screws.

24. Attach the angle brackets to the rails of the frame with wood screws as shown.

25. Cut a plexiglass panel to fit along the back of the panels. This plexiglass panel will be sandwiched between the frame and panels to protect the back of the panels from direct weather. It should not be airtight. Drill 1-inch holes in the panel to allow the cables to exit. This is a critical component. Omission will result in premature failure of the solar cells.

26. Self-tapping metal screws were used to secure the panels to angle bracket. Drill through the solar panel frame with great caution. Use a padding block to keep from drilling into (and ruining) the solar panel.

27. The frame-plexiglass-solar panel sandwich is shown below. The carriage bolt is installed.

The LORA antenna is shown mounted in the image above.

28. Use an outdoor grade silicone caulk to seal all joints. Be generous and thorough. Insects (esp. ticks and ants??) seem to be attracted to the enclosure. It must be sealed very well.

29. Use an exterior grade paint on all wood surfaces. Several coats on the leg bottoms are recommended.

Solar cells were installed after painting.

Congratulations! You are now ready to install hardware and cabling.

Security

The installation of the doghouse and magnetometer tube will be remote. We secured our lid to the box with two 3 in exterior screws driven through the sides. This makes for a simple but effective 'lock' for the box. Ideally, access to the box will be needed only several times per year.

Signage

Anyone (especially administrators and authorities) coming across the box in the field should be able to easily determine the purpose of the device. Below is the signage we printed and laminated to the Coe-Brown box.

UNH-CBNA
Space Weather Underground

Magnetometer Experiment

If there are concerns or problems, contact Scott Goelzer: sgoelzer@coebrown.org, 603-942-5531e218
Dr. Charles Smith: Charles.Smith@unh.edu
Dr. Harald Kucharek: harald.kucharek@unh.edu

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