Installation and calibration of the cosmic-ray solar moisture probe

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Dear User,

This document is not intended to be a full technical document with complete and detailed instructions. Here I have provided a basic procedure, some helpful diagrams and hints, and the list of tools I use to do the installation and calibration. Hopefully the diagrams are sufficient to get you through the relatively straight forward installation and calibration procedures. There are many ways of doing the installation and calibration, but after installing and calibrating 35 instruments to date, the following document is the set of methods we have adopted for the COSMOS project. Please consult HydroInnova, BP, and Questa Instruments directly for additional technical assistance and individual manuals. Lastly and most importantly, don't electrocute yourself with the solar panel or car battery leads. That is probably the only way one can really injure themselves during the installation and calibration.

Sincerely,

Trenton Franz
University of Arizona

Summary of Installation Procedure

1. Unpack all equipment in the lab to see if you have all cables and parts. Familiarize yourself with the pieces and how they would fit together in the field before heading out.
2. Compile all the additional parts and tools needed for the installation that were not included. Typically a trip to Home Depot or Ace Hardware is sufficient. However, the 2 inch to 3/4 inch bell reducer can be difficult to find so a trip to a plumbing supply store may be necessary or finding a replacement piece.
3. Build the solar panel in the laboratory. This is always tricky to do the first time and the BP instructions are terrible. Use the following diagrams as a guide but it may take a few iterations to get it right. **Make sure to leave the panel covered with the cardboard and tape the live ends**. In the end, common sense is your friend.
4. On the day of the installation, first secure the 2 inch pipe in the ground with the threads above the ground surface. Typically we bury this 2-3 feet and use a 50 lb bag of quick setting concrete for stability. We typically like to mount the instrument box 3-5 feet off the ground depending on expected snow level, water level, and potentially understory vegetation. The instrument should not be buried as the sensor support volume and neutron counts may be affected. Let the concrete dry for half an hour and then start mounting things.
5. With the built solar panel setup, connect it to the top of the 2 inch pipe with either hose clamps or U-Bolts. Mount the solar panel at an ~30 degree angle from the vertical in a South facing direction with a slight turn to the East (~5 degrees) for good morning sun. I have found hose clamps provide a tighter connection as the flat part of the U-bolt tend to let the panel get moved around in the wind. If you can find a circular U-bolt back then this will make a tight fit. If you use U-bolts, make sure you thread the U-bolt in the solar panel bracket before completing its construction as sometimes the U-bolt is too large to thread through afterwards.
6. Screw the satellite antenna to the 3/4 inch pipe. Next thread the 3/4 inch pipe to the 2 inch bell reducer. Finally screw the whole setup to the 2 inch pipe in the ground. Make sure you are tall enough or have a ladder.
7. Mount the instrument box to the 2 inch pipe with two U-bolts making sure the box is upright. Again make sure the instrument box will be above snow, water, and potentially fast grow understory. Place the instrument box on the opposite side of the solar panel so you can open the door.
8. Connect the coaxial cable from the satellite antenna to the top of the instrument box. Thread the solar panel wire into the instrument box through a port on the bottom left hand side of the box. **MAKE SURE PANEL IS COVERED AND LEADS ARE TAPED!**
9. Construct the electrical leads from regulator to battery. Insert battery into the bottom of the instrument box. Attach circular end of electrical leads to battery terminals and forked end to solar regulator starting with the negative (ground, typically black) lead first. The numbers on the regulator indicate the order to which things should be wired (guess how many sites it took me to figure that out!). **MAKE SURE NOT TO CROSS THE WIRES ONCE THEY ARE CONNECTED TO BATTERY!**
10. Next wire the solar panel starting with the negative lead, followed by the positive lead.
11. Wire the load wires (if not already connected) and connect power cable to the datalogger near the switch on bottom of datalogger. Note, we typically include a 90 degree locking connecter so make sure to align the plug and give it a ¼ turn to lock it in place.
12. Uncover solar panel, make sure ethernet cables are all connected between the NPM's and datalogger, and external SD card is in locked position.
13. Use switch to turn on instrument. The firmware will be read automatically and the instrument will try to transmit data every hour. LED's on top of NPM's indicate when a neutron is counted, so make sure these are lighting up every 3-5 seconds.
14. Secure excess solar panel cable to 2 inch pipe. Typically I use black colored zip ties.
15. Lastly, use silicon to waterproof all external ports, including the solar panel black box on the back of the panel, the solar panel cable going into the instrument box on the bottom left, and the two satellite antenna coaxial cable connections.
16. See soil calibration procedure

List of tools needed for typical installation and calibration

Items in Picture

1. 2 inch to 3/4 inch bell reducer (needed extra connectors as this piece is often difficult to acquire)
2. 3/4 inch by 6 inch threaded pipe
3. 2 inch (2 1/4) U-bolts (Need 2 for mounting instrument box)
4. Hose clamps of various sizes (Need 2 to mount solar panel)
5. Electrical wires, connectors, and wire stripper for connecting regulator to battery
6. Electrical tape (2 rolls needed for taping 108 soil cans)
7. Volt meter for diagnostics (optional)
8. Crescent wrenches
9. Wrenches (1/2 and 9/16 inch for most U-bolts)
10. Large and small screwdrivers, flat head and Philips
11. Silicon for waterproofing instrument box and connections
12. Lock for instrument box (optional)
13. Wood chisel for separating soil rings in split tube sampler during calibration (optional)

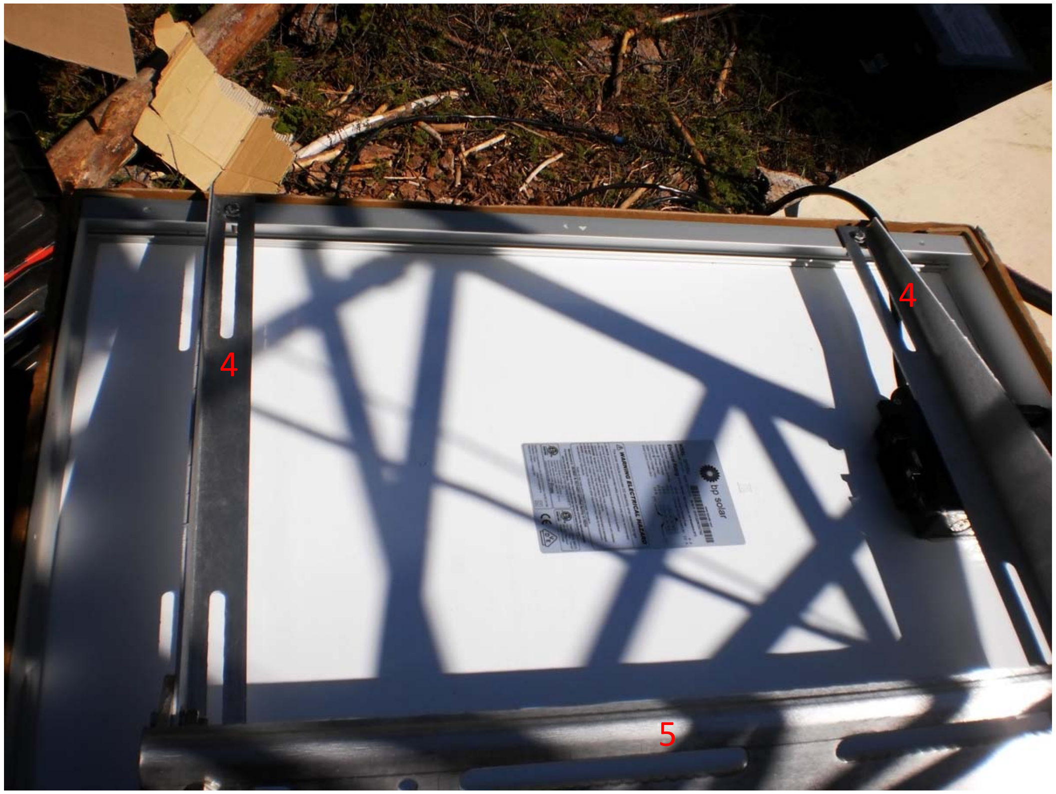
Additional Items not pictured

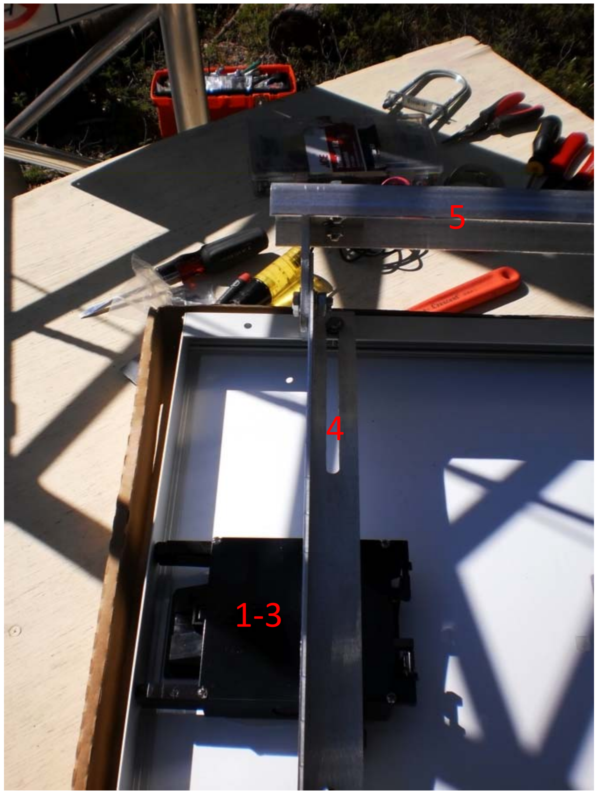
14. Zip ties of various sizes (Optional, black color preferred)
15. Threaded 2 inch by 8-10 ft pole
16. 50 lb bag of quick setting concrete and 1 gallon of water
17. Shovel, sharp shooter for digging post holes preferred
18. Socket set with extenders (Optional but maybe useful)
19. Spilt tube auger for soil sampling (AMS sells a nice one)
20. 108 soil tins for full calibration (bring a few extras)
21. Field notebook

Useful Diagrams: Solar Panel

I recommend constructing the solar panel in the laboratory before installation, lots of nuts and bolts to lose and it can be time consuming the first time you put one together. The pictures are for the larger panel setup but may be different for smaller panels or different companies.

1. Wire black panel on back first before mounting brackets
2. Knock out disk on side of panel
3. Wire large black cable in two terminals (red to red black to black). TAPE LEADS ON LIVE END!
4. Connect two cross panels to back of solar panel (use two inner holes for setup in picture)
5. Connect perpendicular cross piece and tighten when you have desired angle (approximately 30 degrees from vertical)





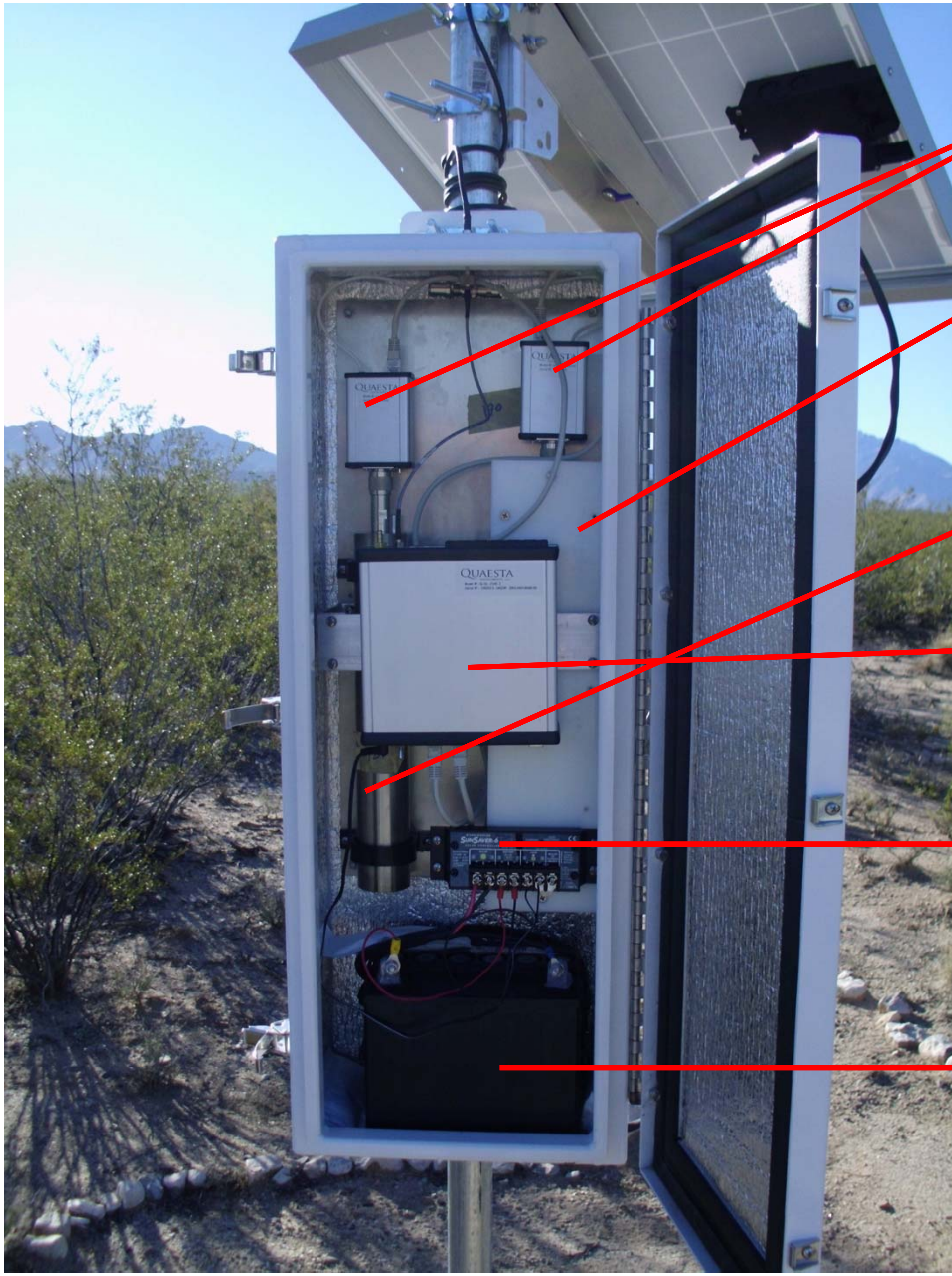
Useful Diagrams

Satellite Antennae

Solar panel and mounting kit

Instrument Box

Useful Diagrams



Useful Diagrams

¾ inch by 6 inch pipe

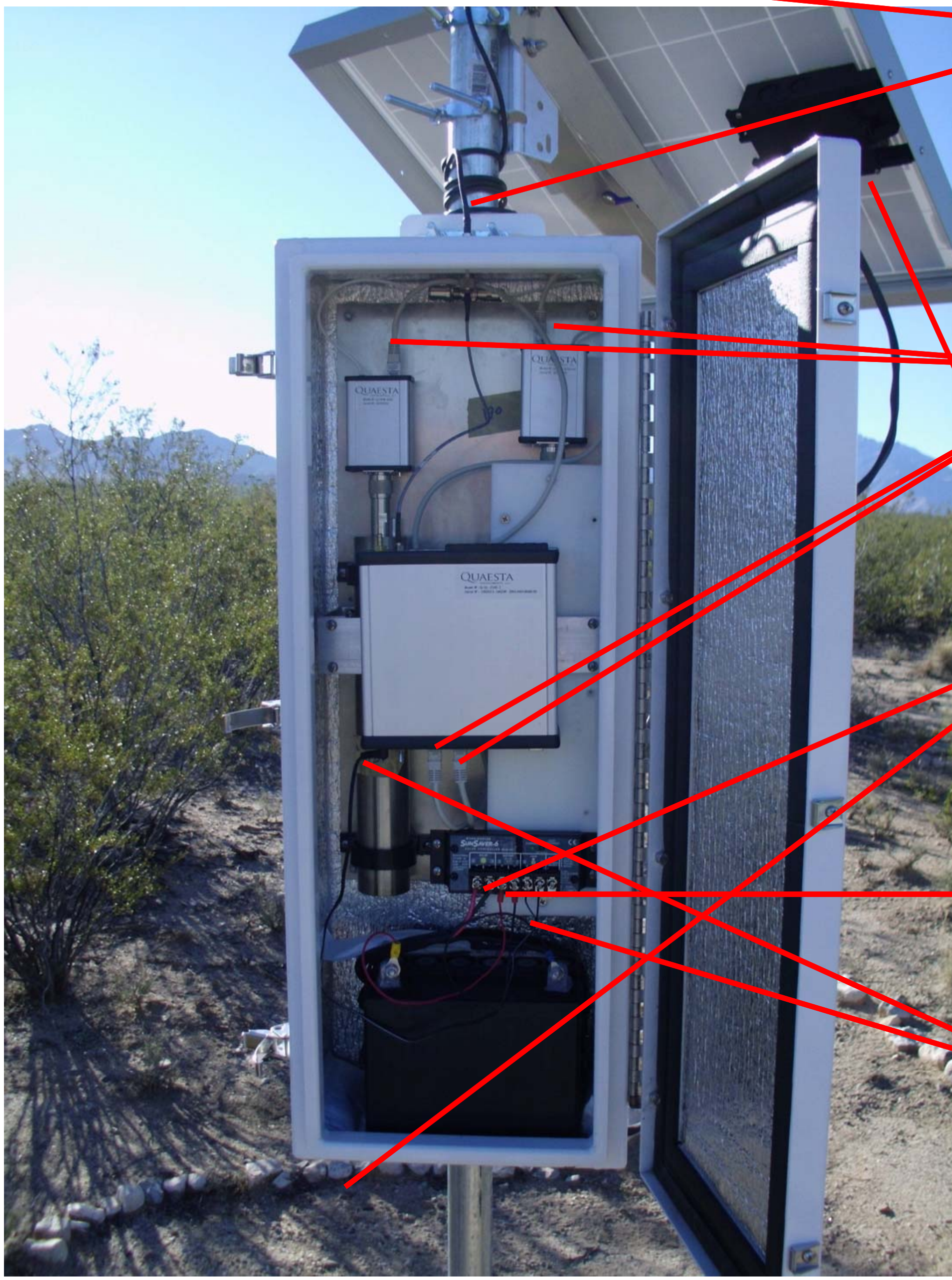
2 inch to ¾ inch bell reducer

2 to 4 inch Hose clamps (U-bolts alternative)

2(2 ¼) inch U-bolts

2 inch by 8-10 ft threaded pipe

Useful Diagrams



Coaxial cable connects sat. antenna to datalogger

Ethernet cables from NPMs to datalogger (SDI interface, order doesn’t matter)

Solar panel cable, goes through vent in box and wired to regulator

Electrical leads from battery to regulator

Load leads providing power to datalogger

Summary of Calibration Procedure

The key information we need is an estimate of **volumetric water content, bulk density,** and **lattice water** in the footprint (~300 m radius circle to a depth of ~30 cm). These factors will affect the calibration function when converting from fast neutron counts to volumetric water content.

Pore water and bulk density: The distribution of pore water is highly variable, so this requires lots of sampling to get a good estimate of the average. For the calibration procedure, we typically use the AMS split tube sampler with six 5 cm rings covering a depth of 30 cm in the vertical. We have found that collecting samples at 18 locations and 6 depths (108 total) provides a good estimate of the mean volumetric water content with low standard error. The sample locations are every 60 degrees (0, 60, 120, 180, 240, 300) and radii of 25, 75, and 200 m. This pattern was chosen such that each sample location (and representative area) is given equal weight in the COSMOS probe sensitivity (sensitivity dies off exponentially from sensor). Note: these points don't need to be exact (within a meters is sufficient), but most importantly they should be representative of the whole sampling quadrant. From a known volume sample, the bulk density and volumetric water content can be estimated by gravimetric methods. The standard gravimetric method is to obtain the wet soil weight and dry soil weight following oven drying at 105ºC for 24 to 48 hours. Note, we tape the soil cans in the field to prevent change in water content due to drying. A sample spreadsheet of the procedure calculations is also provided.

Lattice water: This is the amount of water contained in the mineral structure of the soil. This analysis has to be performed in a laboratory. We typically use Acculabs of Ontario Canada. We know that lattice water varies significantly around the US and is a function of both the soil formation (volcanic areas have higher lattice water) and soil weathering (more lattice water with higher clay contents). Overall the distribution of lattice water is poorly understood and we are currently compiling a national database. Fortunately we have found lattice water does not vary that greatly around a COSMOS footprint, so we typically collect 4 samples for an estimate of the average. The first 3 samples we obtain are point samples collected at 3 of the 18 pore water sampling locations. Typically, we pick 3 different radii and 3 different directions. At each site, collect ~70 gm of soil from each layer from 0-10 cm, 10-20 cm, and 20-30 cm, for a total sample of 200 gm. The final sample is a composite sample. Following oven drying and weighing of the pore water samples, we typically take ~2 gms from each can as a representative sample. Please send these 4 samples back to University and Arizona and we can send them into the lab for analysis and add them to our database.

Useful Diagrams: Soil Auger and Sampling

The photographs show the split tube sampler from AMS with the 6 rings used for volumetric sampling. Also shown in photograph are useful items including: a strap and large crescent wrench for unthreading slide hammer from core when locks together, anti-seize paste for lubricating threading.

In the field, the slide hammer is used to insert the core which is subsequently dug out to prevent shearing of pieces.

Finally the soil cans are filled and taped for later weighing in the laboratory.

Pore water sampling diagram

Black x's denote 18 sampling locations in COSMOS footprint.

Sampling locations are representative of 18 wedges defined by red circles and line.

Wedge areas are equally weighted due to sensitivity of COSMOS sensor.