Astronomy Power Box Project
by Anna Morris

Caveat/Notice:
The following is my own personal project and how I went about accomplishing it. I am not a licensed electrician nor can I guarantee my wiring will work for your situation. I am not responsible for any problems/issues you might have by following my example. Please make sure you know what you are doing as far as the wiring, fuses, breakers, etc before you undergo such a project.

Introduction:
One project I have been wanting to do for a while is a power box that I can take in the field or use at home for my astrophotography. I have a couple "Power Packs" but their amp-hour capacity is very limited and to make it worse, they do not cope well with frequent moves that the military has required as they tend to end up on a boat somewhere or in storage for months before our household belongings arrive and by then are long dead and do not like to hold a full charge anymore. My solution is to make a power box with a deep cycle battery at the heart. Not only will this allow for much longer sessions before my battery power dies, but they tend to do better if they get completely drained (still not recommended, but once every 3-4 yrs should be ok) and if I build a box of my own I can replace the "heart" when it is necessary as opposed to having to buy a whole new "power pack" - a cheaper prospect in the long-run for sure. There are a few commercially available ones, but these are expensive and still do not have the amp hours I would like and I figured that I could build one for the same or less and can customize it, add on as I wish over the years, and it gives me a good fall/winter project. Before I began I wanted to thoroughly plan this out as I had not done anything with Electrical Engineering knowledge since multiple college courses and had only done minimal wiring in the years since (on a previous astro project). I needed a refresher course to jog my memory and make me feel comfortable. I knew what I wanted to come up with in the end and the rough layout of the wiring, so I read up, asked friends, and sent my questions to others that had done similar projects. After a few days I had acquired the knowledge I needed and had my plan all laid out and began ordering parts.

Requirements:
Lets start with the requirements for my particular box. They are based on my current setup, with a little room for growth, and a few "nice" things I wanted to add.
* 140Ah deep cycle battery, 12v
* 6 cigarette lighter-type sockets, all fused at 10A
* 7-port USB hub with out-socket to computer and 12v to 5v converter
* Power Inverter with two 120V sockets (I determined that a 450W inverter would suit my needs)
* Digital Voltmeter (while I liked the look of the analog ones, I wanted a more accurate reading)
* Battery Tender for charging the deep cycle battery

Math:
You might be curious what #s I used to come up with my requirements. I knew I wanted 6 lighter-type sockets based on my current devices and accessories I might put on. I also wanted at least a 7-port USB hub as I current have a 4-port and am using all of the ports so wanted to have a little extra room in this box. I then had to determine what size I needed for the battery. To calculate this I first had to add up all my current "loads":

First I calculated what size Inverter I would need:
I knew that I would have a 40A max on my distro box, so I first calculated the Max W inverter I could use using the following calculation

DC power (in Watts) = V*A
Then you have to divide by the Inverter efficiency since no gadget is 100% energy efficient. So our final equation would be:

W=V*A/Efficiency
So, V=12V .... A=40A ... efficiency=90% as most I was looking at had that efficiency

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W=12*(40)/(90% inverter efficiency)
W=533

However, I knew that I was planning on a 30A circuit breaker for the whole system. I needed to calculated the optimum inverter size based on this so:
W=12*(30)/.9
W=400

This is with peak stated inverter efficiency. If I assumed that it would not always work at peak efficiency and went with an 80% efficiency I got a max of 450W inverter, knowing that it was exceedingly unlikely I would ever come close to maxing out its potential. I went ahead and went with the 450W, though, as I found a great deal on one.

Next, I needed to calculate the amp draw my devices would have:

Current Devices:	
Atik 314L+	Draw: 0.8A
CPC800XLT	Draw: 1.5A
Atik EFW2	Draw: 0.22A
Dell Netbook	Draw: ~2A, with occasional peaks to 10A
Dew Heater Strips	Draw: 2.05A

Main devices: Total Draw: 6.57A

The Inverter's no-load amp draw is 0.35A so factoring that in brings the devices to 6.92A with no load, factor around 13A (based on random research I did if I plugged in, say a secondary laptop for charging) for an average if loaded brings the max to 19.92A (plus a little here and there for the LED lights, but those should be negligible)

USB Hub: As I was planning a 7-port hub I could have a max draw of 3.5A, however using each port at max draw was unlikely. I did not set up the usual devices that I plug into a hub to test the draw as I do not have a shunt or ammeter (doing this would be ideal, however) so I assumed an average draw from the hub of 1.5A for my calculations [*note: this is just a random assumption by me - I hope to eventually test the draw, but was not able to do this at the time]*

so Min=6.57A+1.5A=8.07A, Max=19.92A+3.5A=23.42A

Assume a 7 hr night and not wanting to drain the battery more than 50% brings the #s to
Min= 91.98A-h, Max=327.88A-h

I would not be using the inverter much, only occasionally, so I wanted a realistic # for figuring my battery size. Therefore I figured up a calculation based on two 7-hr nights with no inverter use and got:

8.07A * 14hrs * 2 = 225.96A-h ..... (the 2 is to factor in only draining the battery to 50%)

Ideally I would get a 225A-h battery based on these #s. Well, such a battery is REALLY heavy (the ones I looked at were around 40kg) so I compromised on a 140A-h battery which was around 27kg as the #s for Amp draw without the dew heaters were more suited to the 140A-h battery. This will not get me 2 full nights in the field with no charging based on the #s calculated, but should get me a decent amount of imaging time before I drop the battery to 50% and was acceptable to me. The 140A-h battery will give me about 9 hrs at the above calculated draw before hitting the 50% mark - and considering the dew heaters won't always be used I will generally get around 11 hrs ... not too shabby!

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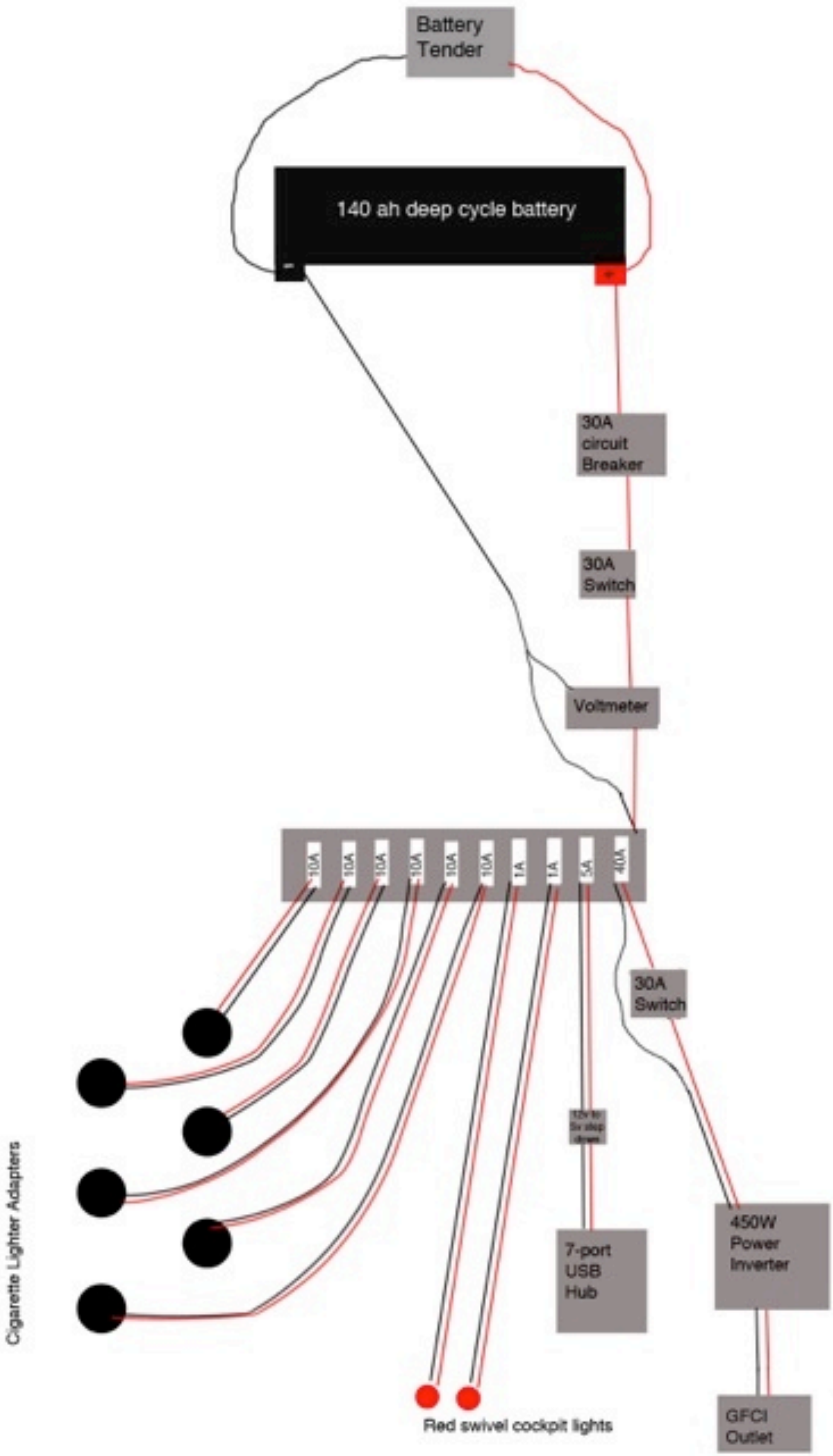
Wiring Diagram: Once I had determined what all I wanted to include I was able to draw up my wiring diagram:



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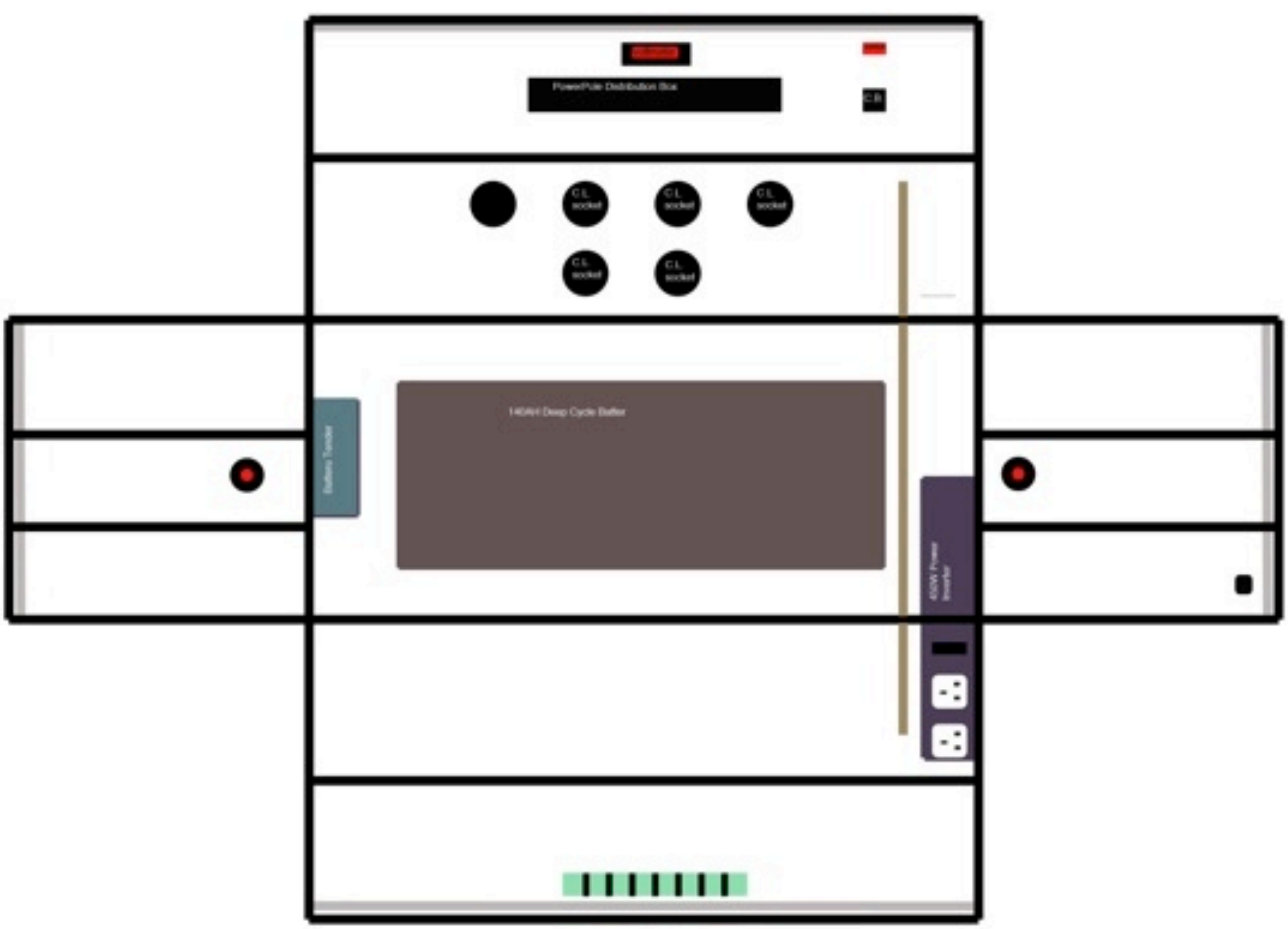
Parts:
All my requirements and wiring plan had been sorted now, so I started part hunting. I was looking for a decent balance between quality and cost (as I was working on a relatively strict budget for this project). As I am currently living overseas and sourcing things locally would be very expensive for me (based on the current exchange rate), I did most of my part shopping online except for the deep cycle battery, which I got from a company in-country that would deliver it for free. These are the parts I went with:

deep-cycle battery:	XPlorer ULTRA Deep Cycle Leisure Battery 140Ah
circuit breaker:	12V DC Car Audio Circuit Breaker Fuse 30A
switch:	12V Red Light tip toggle switch 30A rated
voltmeter:	DC 7-60V Red LED Panel digital Voltmeter
distribution box:	Anderson PowerPole RIGRunner
cigarette lighter sockets:	PowerPole adapter 10V fused cigarette lighter sockets
USB Hub:	Rosewill RHUB-300 USB 2.0 7-port Hub
12v-5v step down:	DC-DC 12v to 5v 25W step down converter
USB plug adapter:	2.5mm right angle DC Coaxial Power Plug to PowerPole adapter
Inverter:	Samlex Sam-450-12 12V 450W Power Inverter
Red LEDs:	Red light swivel cockpit lights
deep-cycle charger:	Battery Tender 022-0157-1 Waterproof 12 Volt Charger

Design Diagram:
After parts were ordered and therefore I had dimensions I redid my design diagram (I had a rough one I started with for concept and deciding what I wanted). I wanted to make sure I left enough room to run the wiring without anything being crimped. The brown vertical line is to show that the inverter will be below the deep cycle battery as I am planning a palette-type lower part of the box that the battery will sit on and with



the inverter below the battery it will isolate the inverter in (the unlikely) case of a spark being thrown, which I had heard was a remote possibility. The design is shown as if you fold open each side panel and with no top. The sides will not open and the CL sockets and AC outlets will go to the outside (via a 1ft extension cord and GFCI outlets), I just showed them on the inside so I knew where I wanted everything. I am planning the front panel (on top) to have the voltmeter, the master switch, and the cigarette lighter sockets. The distribution box and circuit breaker will be mounted on the inside of the same panel (space dependent). The back panel will have the power switch for the GFCI outlets, the outlets themselves, and the USB hub. The two side panels will have the red swivel cockpit lights and one side will have the USB type-B out port while the other will have the out cord for the Battery Tender. Things might get moved around as they need to to fit in the box correctly as I build, but this is the plan as I began.

The Build:

After shopping for wood and paneling that I would need for the box I began with the lower palette section of the box. This is shows with the battery on top. A lower panel board was used for the floor of the box.

I then started on the walls using 1x2” boards. I have cross beams all the way around for both stability and a more solid mounting surface for some of the electronics and internal components.

Next up was the paneling for the front and sides as well as the tie-down strap for the battery. At this point I am leaving the back panel off until I get all the components as several will be mounted in the lower portion of the palette and I will need access via the back to wire everything.

Next came the latch connectors and the edging (just for aesthetics) ... Handles on the sides and the rotating cockpit red LEDs as well. Inside the Battery Tender has been mounted on the side. A first coat of paint as well for the portion that was done.

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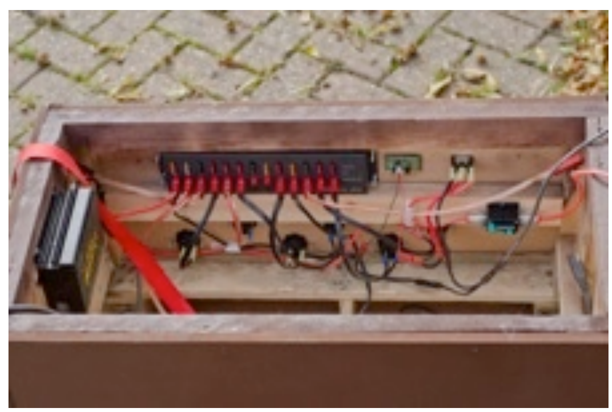
From the back you can see the mounted Battery Tender as well as the mounted USB hub down in the palette section. Keep in mind - a USB hub requires 5V not 12V so a step-down converter is required. If you do not put this in you can possibly fry your USB-powered devices! I will show a close-up of this later in the wiring images.

Back panel was fitted over the USB hub and remaining edge covers were put on. Four 6” pneumatic caster wheels (2 of them locking) were put on. USB-B type out port was installed on the side panel to connect the USB hub to my computer.

Once the Power Pole distribution box and the rest of the wiring came in I was able to work on the main portion of the wiring. The top panel (above the cross bar) has, from L-R, the PP distro box, Voltmeter, 30A switch, 30A circuit breaker. Below the cross bar are the six cigarette lighter-type 12v power sockets. On either side of the box the two red swivel cockpit lights were also wired in. Using the Power Poles made the wiring very simple and no soldering (which I hate to do) was done at all. I will show a labeled larger image of the wiring shortly.



Here is a top-down look at the inside. All the wiring is on the left (for the most part) which is the front panel and you can see the inverter peeking out from the palette below the 140Ah battery. The inverter will be connected to a GFCI outlet which is on the back panel (underneath the flashlight). The battery tender is mounted on the side of the battery with a decent amount of separation and I also have a military flashlight with a red filter inside on a bar I mounted so I can take it out if I need it, otherwise I have it inside the box in case I need to check anything inside out in the dark. The red strap goes below the battery through the palette and also through the side cross bars between the bars and the paneling so it holds the battery down fairly well. All fuses and the circuit breaker are easy access and I can change anything or troubleshoot without having to take out the battery.

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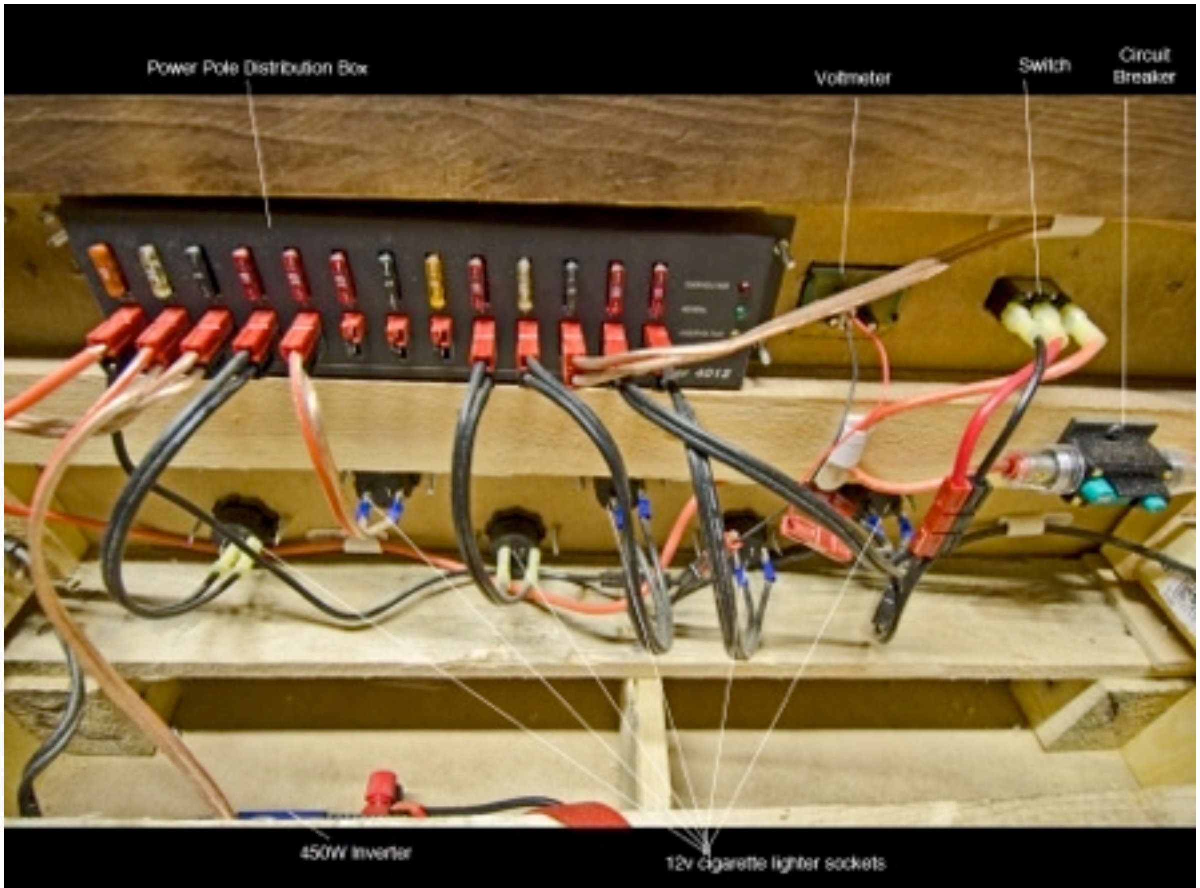
Now for closer labeled images of the wiring.



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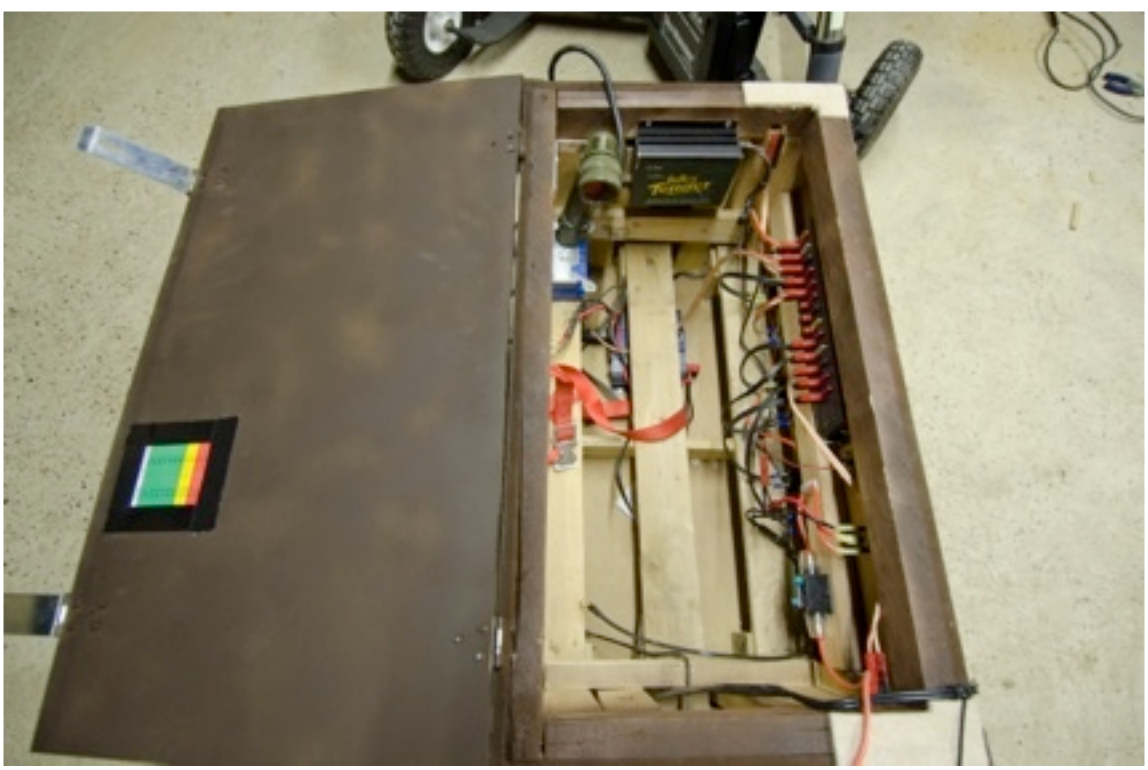
Here are some images of the final power box (pending one more layer of paint):

The Green/Yellow/Red box on the lid is a voltage/state of charge chart.
Top-down view of entire box minus the battery



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From the front with the lid open and battery tied down:

Side view - side with USB out port (from hub), RAM mount for iPhone, and one of the red LED swivel lights

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Front: Carabiner locks with zipper red LEDs, Master on/off, voltmeter, 6 cigarette lighter-type 12v sockets, front air vent (back side of inverter)

Back: GFCI outlet, inverter's power switch, air vent (for inverter) and 7-port USB hub

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Conclusions/Lessons Learned from build:
All in all, a relatively simple build once all the wiring plan was created and design was completed beforehand. I now have a long-lasting, durable power box with room to expand if needed although with a 140Ah deep cycle battery at its heart, that should not be necessary anytime soon.

A few things to note from the build:
* Keep in mind that a USB hub requires 5V not 12V - you will need a step down converter or will blow out your USB-powered devices
* GFCI outlets do not like modified sine-wave inverters (the coil in the GFCI buzzes as a result) ... either get a pure sine-wave inverter if you want to use a GFCI or just go with a regular non-GFCI outlet. I will be downgrading to a non-GFCI one as a result as the buzz will get very annoying. Since I have it all fused and a breaker in this shouldn't be a problem.
* I highly recommend a secondary switch for the inverter. The inverter uses a lot of power (compared to everything else) and is inefficient - I only plan on using it in rare cases and having its own secondary switch allows this without having to waste power by always having it on.
* I separated the inverter from the battery via the palette-type lower section as I have read there is a remote possibility that the inverter will occasionally throw a spark. As such I did not want it right up against the battery. This setup also allows me to route some of the wiring underneath the battery rather than around it and avoids cluttering up the inside. This will, as a result, allow for better airflow and ventilation.
* The Battery Tender does get warm when charging and if closed in can get hot. I would not recommend leaving the lid down while charging as you will not have sufficient ventilation to keep this cool and to prevent gasses from your battery potentially igniting (a remote possibility, but if you have it in very close proximity to the battery and don't allow airflow then you should be aware of this)
* I used Marine-grade cigarette lighter sockets. I chose these as my location can get very humid and dew tends to collect on everything. These Marine sockets are water-resistant and have a cover to keep out dew when not in use.
* Keep in mind that a battery as large as I used is VERY heavy. Using small wheels would have made the box immovable. This is why I chose 6" pneumatic casters. I should be able to roll over any terrain I would be bringing my scope to with these on.

Based on my tests by taking darks the last few days (while running everything on the scope, dew heaters, and USB hub just to see how the box would do) it seems that I can run this longer than my calculated time. Once I actually get a clear night I will be able to see just how this does out under the stars. It's nice to finally be rid of all the small power tanks that won't hold a charge and require me to switch power sources multiple times throughout the night. I had fun planning out and building this - if you undertake a similar project I hope you will too!