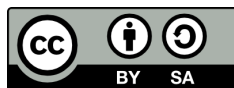


STN **HANDBOOK**

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CENTER FOR **ASTROPHYSICS**
HARVARD & SMITHSONIAN

 **Libre Space**
Foundation

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Welcome to the Library Space Technology Network (LSTN)! This handbook will serve as an evolving reference guide to help your library understand, build, operate, and troubleshoot your satellite ground station. As the LSTN team writes new chapters, we will mail them to you so you can add them to your library's physical handbook. Materials will also be made freely available online in PDF format with clickable links at: <https://lstn.wolba.ch/handbook>

Throughout the LSTN pilot, we will be asking for your feedback on this material and your community's experience of working with the LSTN ground station kit. We hope to use this information to work out any potential issues before expanding LSTN to other public libraries. While working with your library communities and library staff on this project, it would be very helpful for us if you kept in mind these questions:

Where are the roadblocks?

What assumptions have we made that would need to be corrected to scale this project?

Are there any financial, technical, or social barriers that need to be overcome?

We aim to make the handbook as comprehensive as possible, but we know it won't answer all your questions. Please don't hesitate to reach out to us at any time.

Primary LSTN Contact: Nico Carver, ncarver@cfa.harvard.edu

ABOUT LSTN

Background

The John G. Wolbach Library at the Center for Astrophysics (a collaboration between Harvard University and the Smithsonian Institution) has partnered with the Libre Space Foundation to create new infrastructure to support small satellite missions and enable public engagement with space technologies. LSTN is part of this new collaboration, and your library is part of the LSTN pilot. Our goal with the LSTN pilot is to work with you to build and install a small satellite ground station on your library's property. We also hope to work with you to develop educational activities to support your community's use of their new ground station and lower the barrier for entry into space-based science. LSTN has been funded by the Alfred P. Sloan Foundation.

Team



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Libre Space Foundation / SatNOGS

<https://community.libre.space/>





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To whom it may concern:

The health and safety of participants in the Library Space and Technology Network (LSTN) is of utmost importance to us. We have done everything in our power to minimize the risk of injury to project participants both in the design of the ground station kit, and the proposed activities. This letter will address: building, installing, and operating the ground station.

Building the Ground Station


The ground station has been designed specifically to minimize the risk of injury when building it. To this end, the build does not require a soldering iron, power tools, or cutting tools. While we believe the chance of injury is small, we would still advise that the build only proceed under adult supervision.

Installing the Ground Station

Please take all necessary precautions when installing the ground station on your library's roof. The roof should be clear and dry during installation. If a ladder is needed, please have a spotter at the base of the ladder. Please engage with professionals who are cleared to work on your roof if necessary.

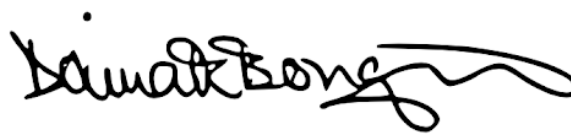
Operating the Ground Station

Operation of the ground station is no more dangerous than operating the radio in your car. The ground station simply receives the radio waves already travelling through space all around us and converts them into usable information. Most possible dangers (RF burn, electric shock, etc.) associated with an amateur radio station are tied to transmitting. These are not possible with the LSTN ground station as it is not wired to transmit. Lastly, there are no known long-term health concerns or pollutants connected to radio receivers.



PAPADEAS PIERROS

Pierros Papadeas
Director of Operations and Founder
Libre Space Foundation

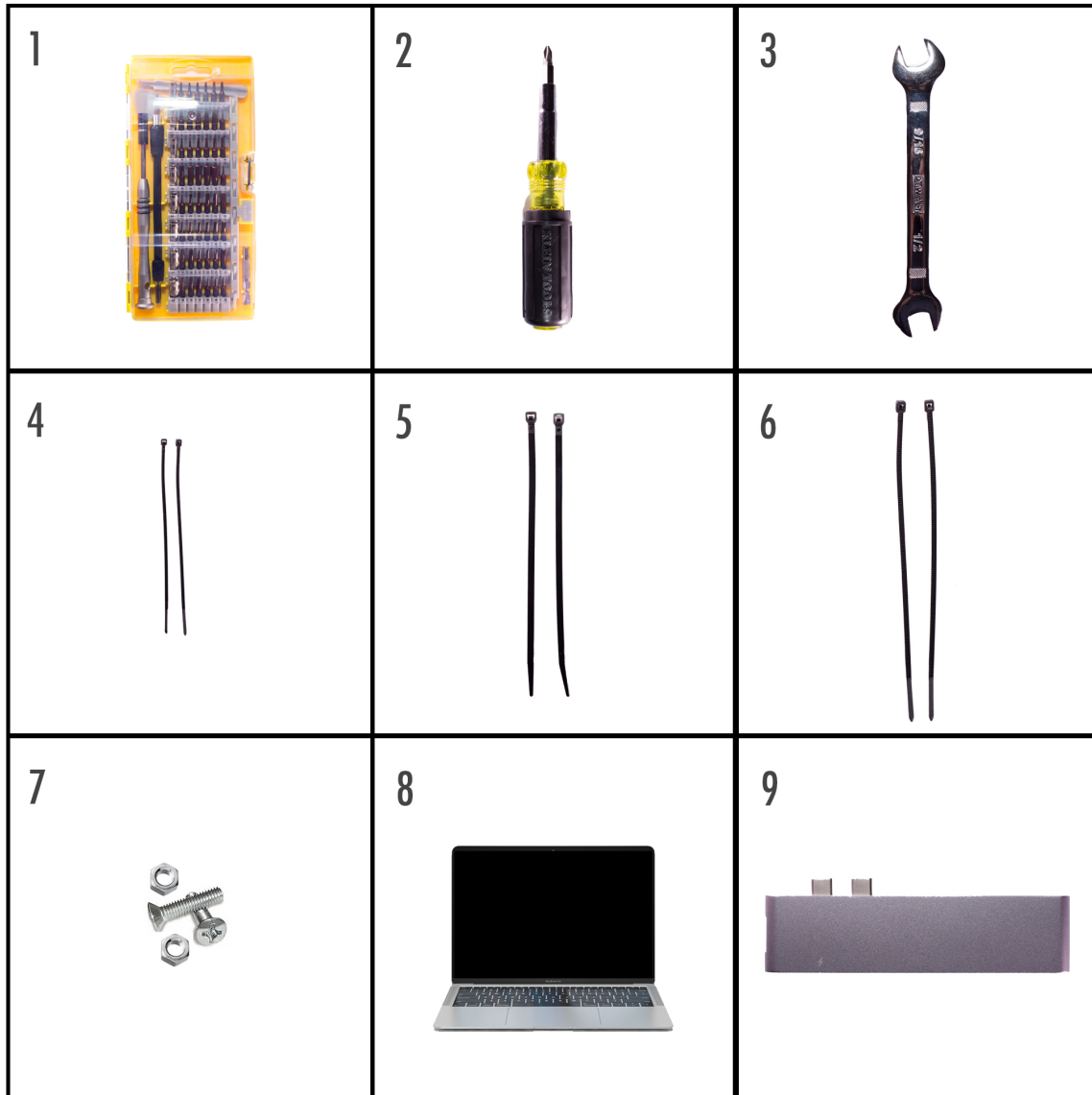


Daina Bouquin
Head Librarian
Center for Astrophysics | Harvard & Smithsonian



Parts - Quick Reference

1. Single Board Computer 2. Power for Single Board Computer 3. SD Card 4. USB Extension Cable
 5. Software Defined Radio 6. RF Cable (SDR to LNA) 7. Low Noise Amplifier 8. USB DC Cable
 9. RF Cable (LNA to Outside) 10. UTP Enclosure Connector 11. Enclosure
 12. Mast 13. RF Cable (Outside) 14. Antenna
 15. Power Over Ethernet Injector 16. Ethernet Cables



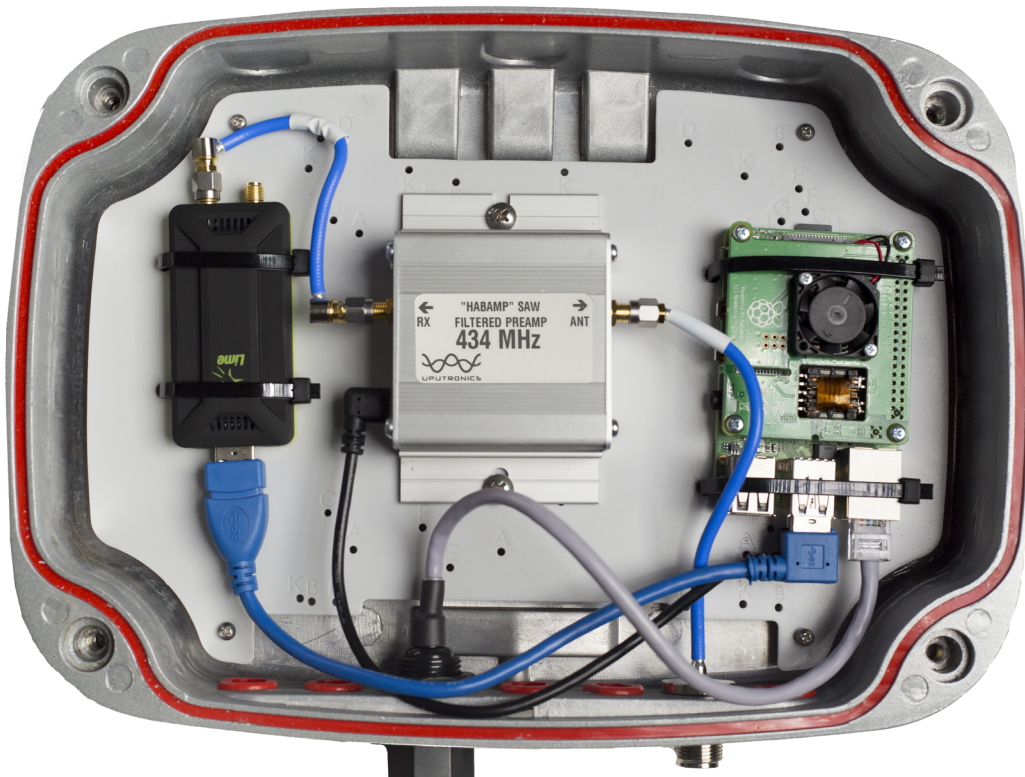
Tools - Quick Reference

1. Precision Screwdriver Set 2. 11 in 1 Screwdriver 3. 1/2 & 9/16 End Wrench
4. Small Zipties 5. Large Zipties 6. UV-resistant Zipties
7. Machine Screws and Nuts for LNA 8. Macbook 9. USB C Hub Adapter

BUILD INSTRUCTIONS

The following sections will familiarize you with each component of the LSTN kit and walk you through how the kit is assembled. In a future mailing, we will provide instructions and materials for a “community build” activity that will be adapted from these step-by-step instructions.

- A. Prepare the MicroSD Card
- B. Install the PoE HAT and MicroSD Card
- C. Assemble the Enclosure
- D. Assemble the Antenna
- E. Prepare for Installation
- F. Configuring the Station (post installation)



A. PREPARE THE MICROSD CARD

Introduction

Most single board computers don't come with an operating system (OS) installed. The most common operating systems in the world for personal computers are Windows and MacOS. The most common operating system for open source projects and single board computers is Linux.

The Raspberry Pi is such a popular single board computer that it has a special version of Linux written for it called "Raspbian." The SatNOGS developers create a special version of Raspbian with software called the "SatNOGS client" already installed, and they release that software on a code-sharing platform called GitLab. A new stable version of the SatNOGS client is shared 1-3x/year; these stable versions are called "releases".

In this first step of the build, we will download the latest release, and "flash" it to the microSD Card. Flashing is similar to just copying the files. We use a special word for it so that people don't think they can just drag and drop the files onto the SD card because that won't work; we must either use a special Unix-style command called `dd` (see Appendix A) or use a simple software program like balenaEtcher.

Parts and Tools Needed in this Section



Parts

3. SD Card



Tools

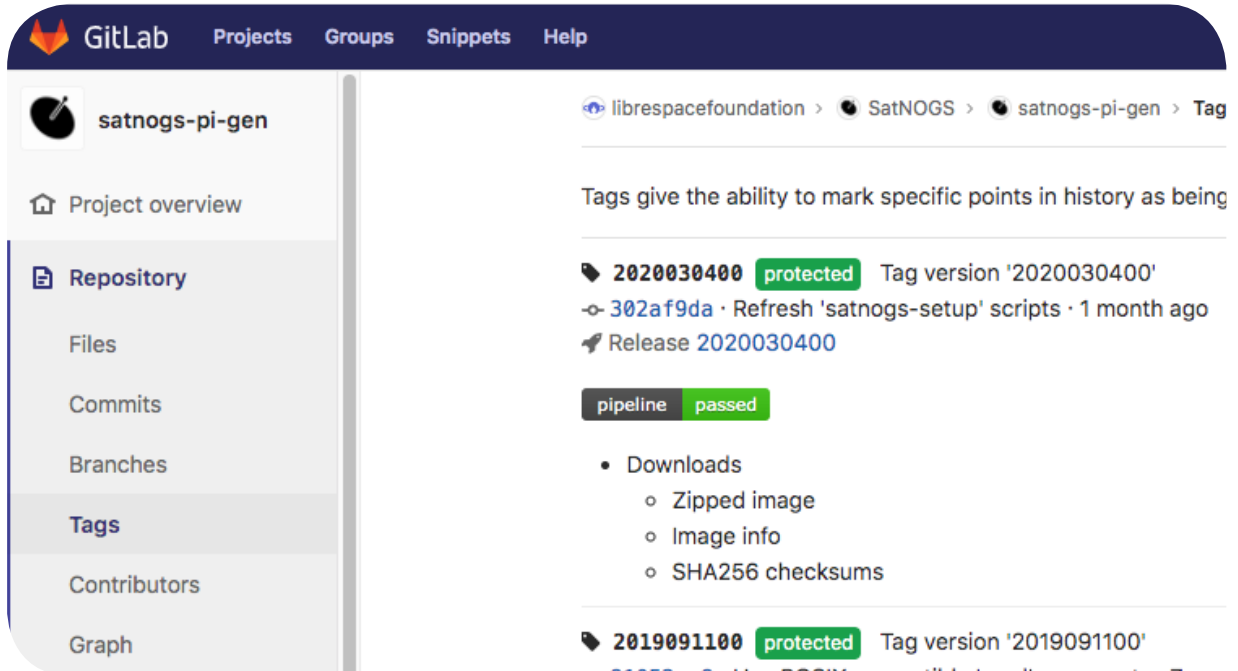
8. MacBook

9. USB C Hub Adapter

1

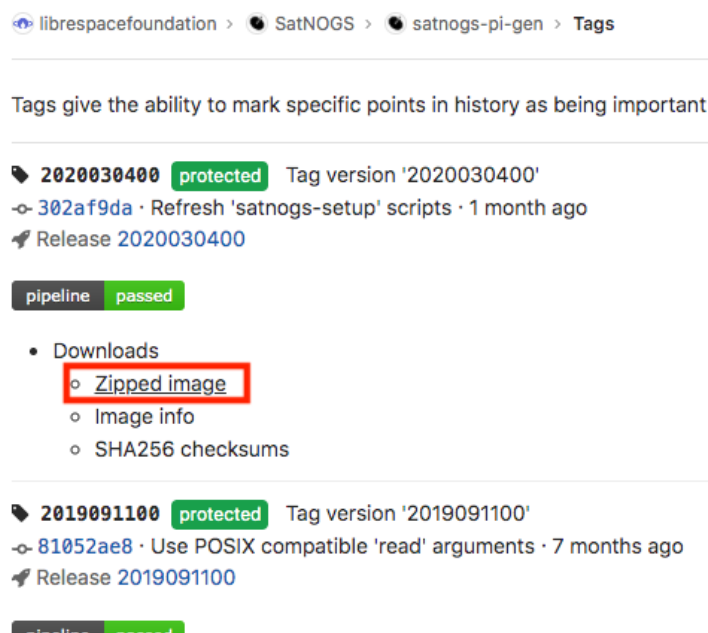
Open a web browser, and go to this page on the SatNOGS GitLab where you will find the latest release of the SatNOGS Raspbian image at the top of the page:

<https://gitlab.com/librespacefoundation/satnogs/satnogs-pi-gen/-/tags>



2

Each release will have three downloads. We only need to download the “Zipped Image”. Click on the word “Zipped Image” on the most recent release to download it. The file will take a few minutes to download. The other two files in the Downloads list are text files with information about the image that you can download if interested.

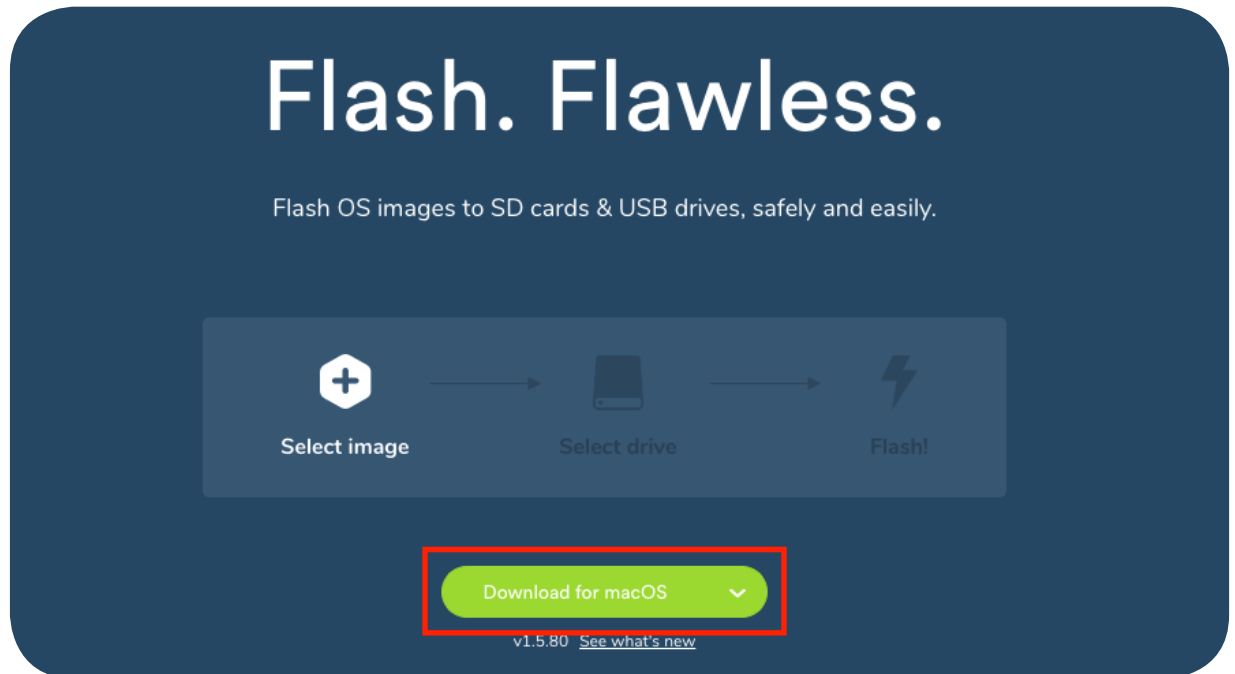


3

While the above is downloading, open a new tab and go to:

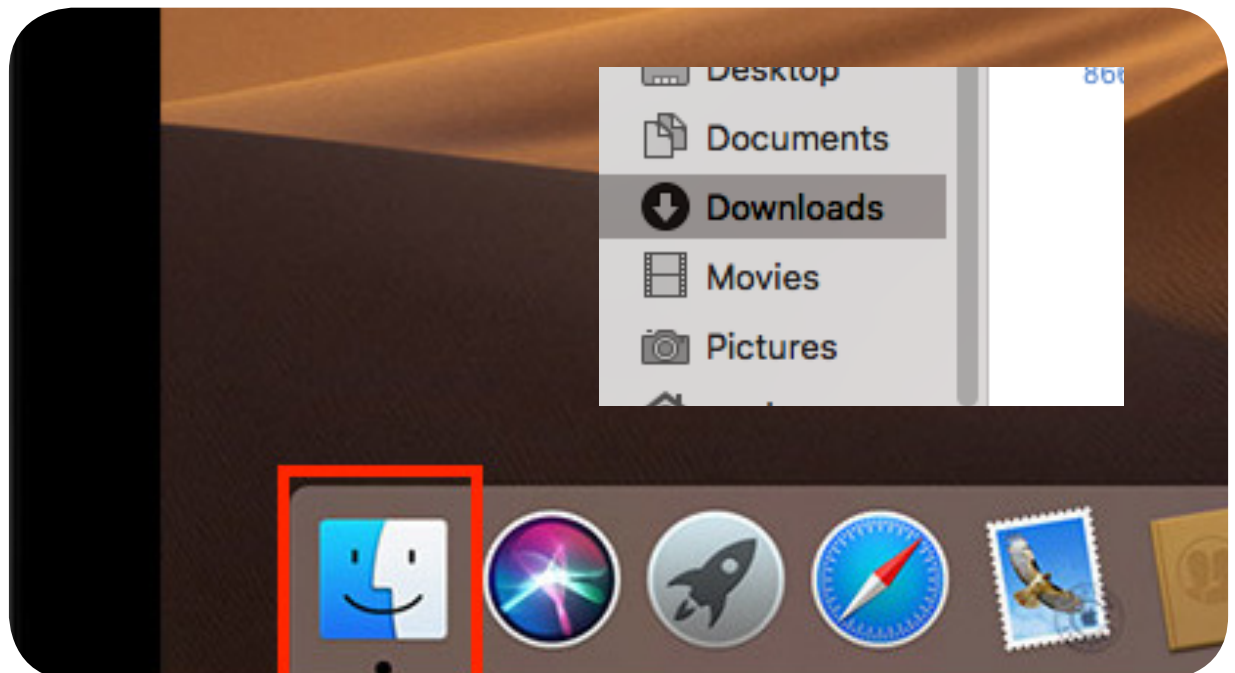
<https://www.balena.io/etcher/>

Download the balenaEtcher software from the homepage. If you are not able to download software, or there is any issue with this method, please see Appendix A for an alternative method using the command-line.



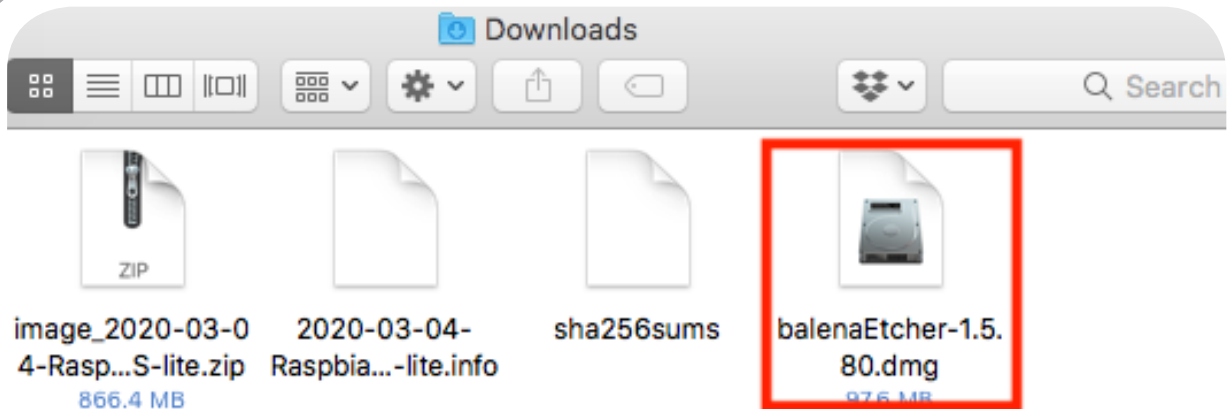
4

Navigate to the “Downloads” folder on your computer. If using a Mac, click the Finder icon and then “Downloads” should be on the left-hand side of the Finder window.



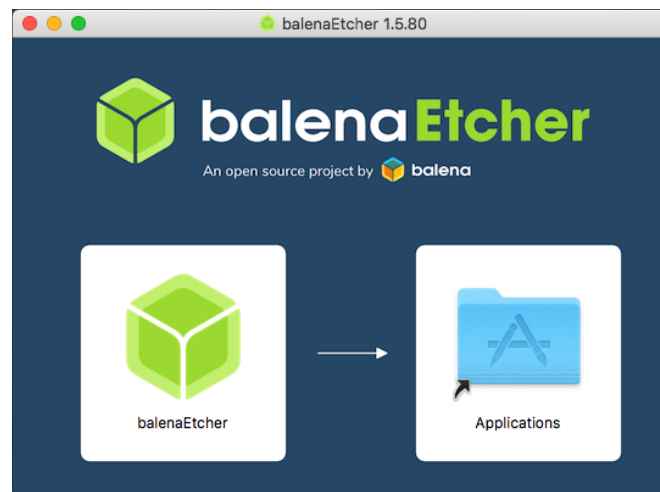
5

Find the balenaEtcher installation package and double-click it. If on a Mac, it will end in .dmg.



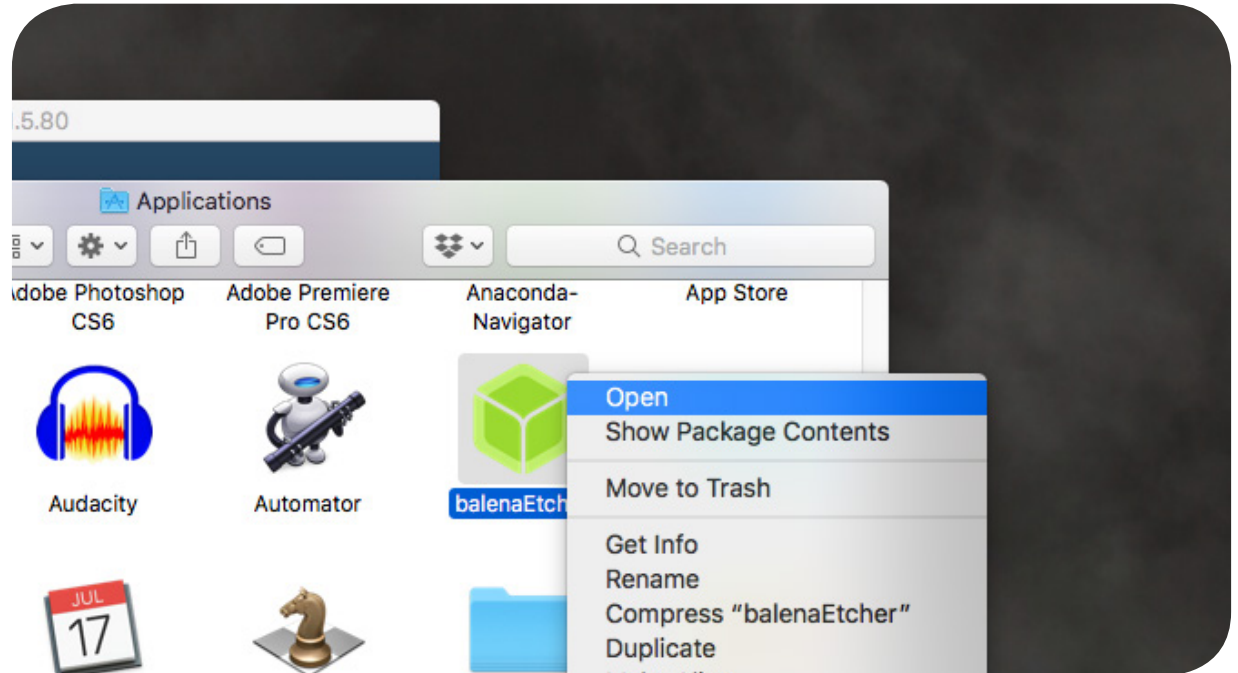
6

Follow the instructions to install the program. If on a Mac, drag the balenaEtcher app to your applications folder.



7

Open the balenaEtcher application. If it asks about running an application downloaded from the internet, click that this is OK. On Mac, you might need to right-click and then click Open the first time you open the application to bypass Mac's default security setting.



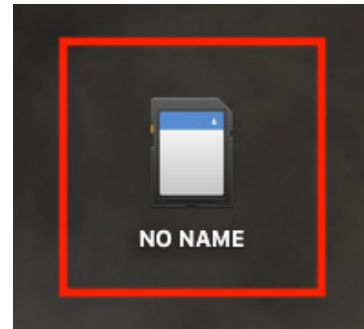
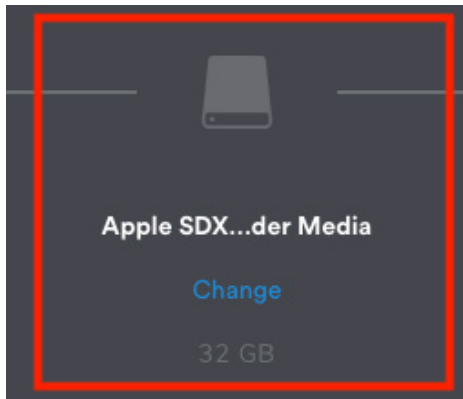
8

Insert the microSD card (Part 3) into the included SD Adapter, and then insert the SD Card (upside down) into the USB Hub Adapter (Tool 9) connected to the Macbook (Tool 8).



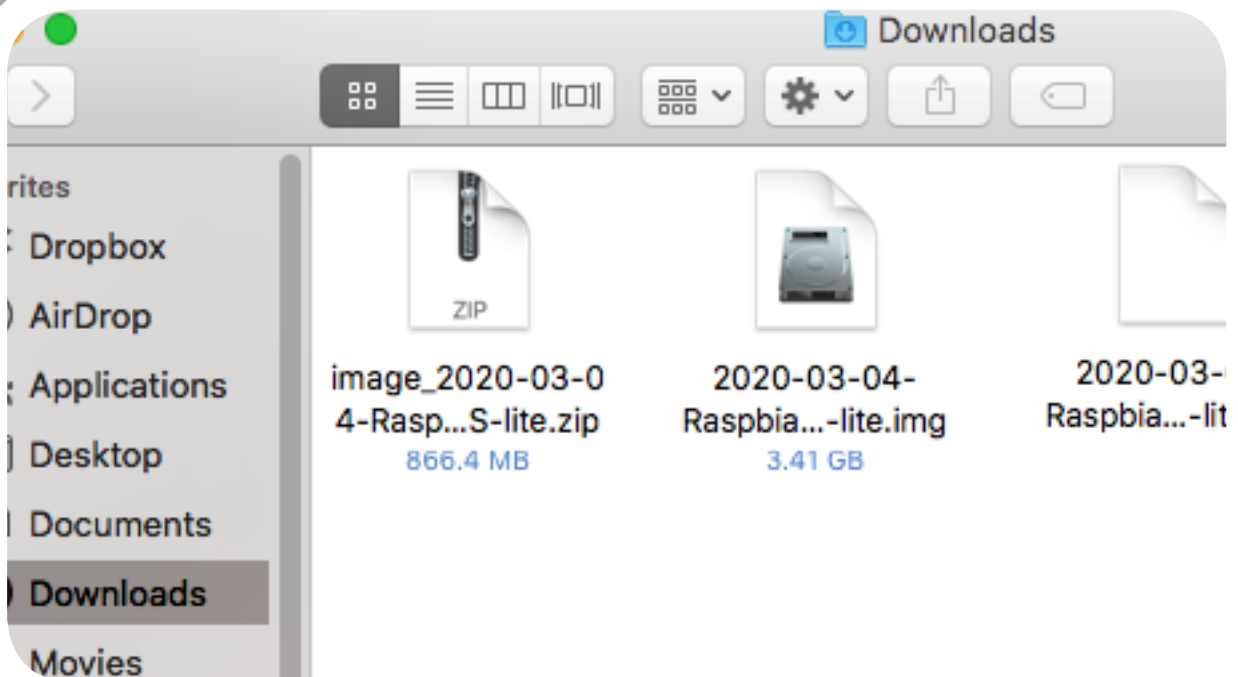
9

The SD Card will appear on the Desktop, and likely be called “Untitled” or “NO NAME”. You should also see that it becomes selectable in the middle of the balenaEtcher application.



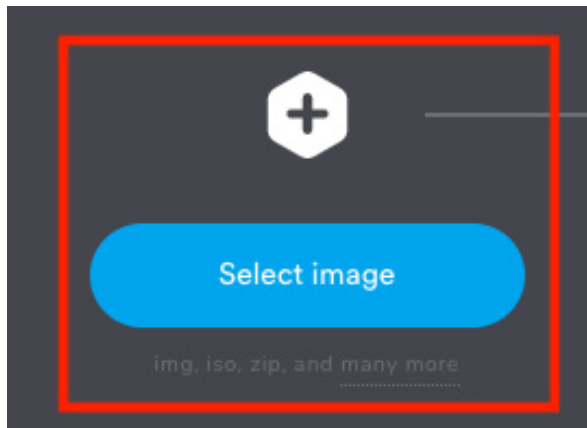
10

Go to your Downloads folder and find the SatNOGS zip file. Double click it, and you should see a file ending in .img appear.



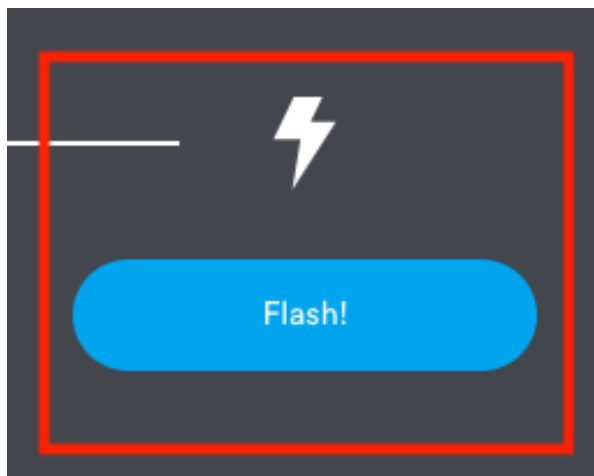
11

Go back to the balenaEtcher application. Click the blue Select Image button and choose the .img file in your Downloads folder from step 10.



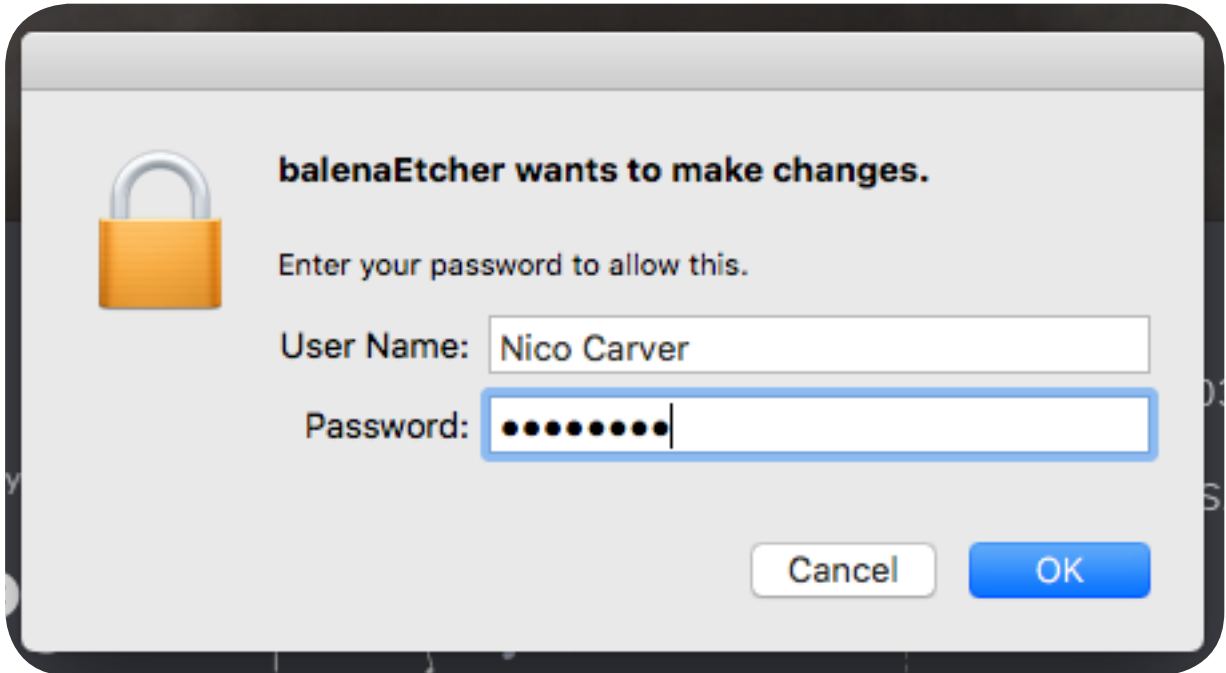
12

Click the blue Flash! button.



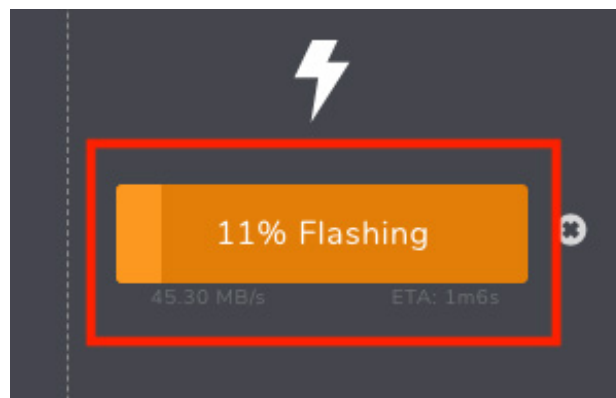
13

Type in the password you use to log in to the computer, and click OK.



14

Wait a few minutes for it to flash (copy) the SatNOGS software onto the microSD card.



15

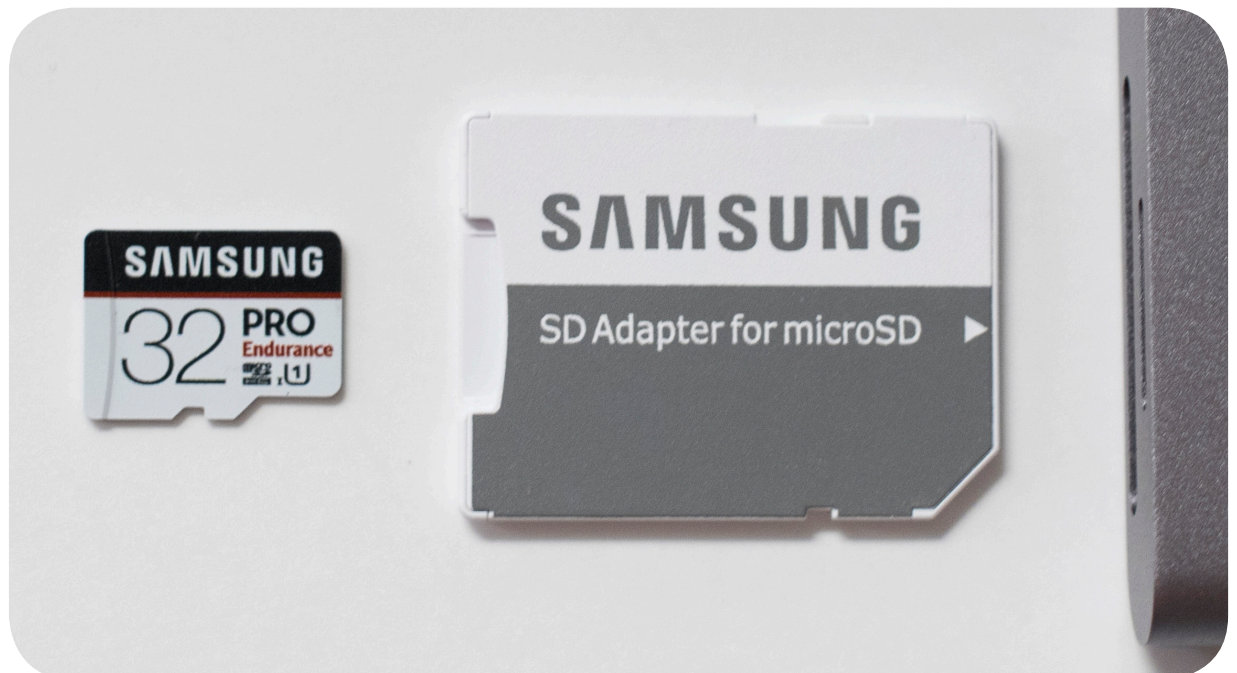
Wait until you see "Flash Complete!"

A dark gray rectangular box with rounded corners. On the left is a green circle containing a white checkmark. To its right, the text "Flash Complete!" is written in a large, bold, white sans-serif font. Below this, there is a smaller green circle followed by the text "1 Successful device" in a smaller, white sans-serif font.

✓ **Flash Complete!**
● 1 Successful device

16

Remove the microSD Card and SD Adapter from the computer.

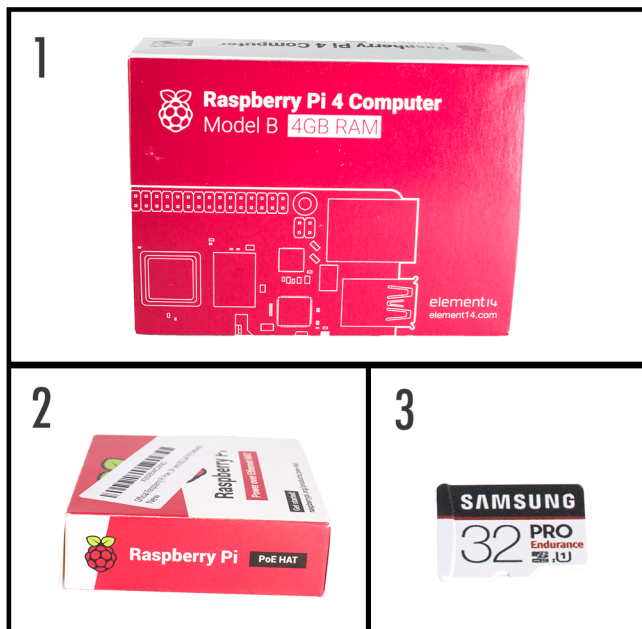


B. INSTALL THE POE HAT AND MICROSD CARD

Introduction

The LSTN Kit uses a Raspberry Pi as the Single Board Computer to control the ground station. Before we can install the Raspberry Pi in the Enclosure, we need to physically install two essential peripherals: a PoE HAT and an SD Card. PoE HAT stands for Power Over Ethernet Hardware Attached on Top. It allows the Raspberry Pi to receive power from the Ethernet Cable that is also being used to connect the Pi to the Internet. This simplifies the design of the ground station by only having to run one cable from inside the building to the ground station on the roof. We will also install the MicroSD card that we prepared in the previous section.

Parts and Tools Needed in this Section



Parts

1. Single Board Computer
2. Power for Single Board Computer
3. SD Card



Tools

1. Precision Screwdriver Set

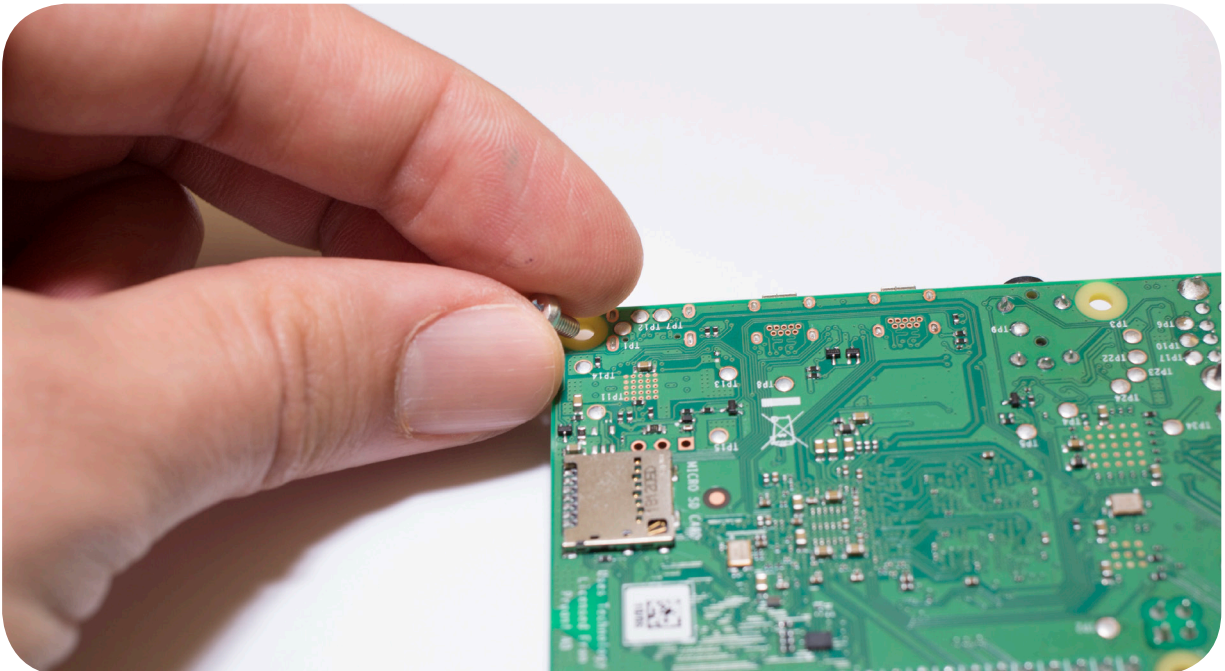
1

Find a clean, well-lit surface to work on. Take the Raspberry Pi and the PoE HAT out of their packaging. From the Precision Screwdriver Set, take out the handle and insert a small Phillips bit (#2.5).



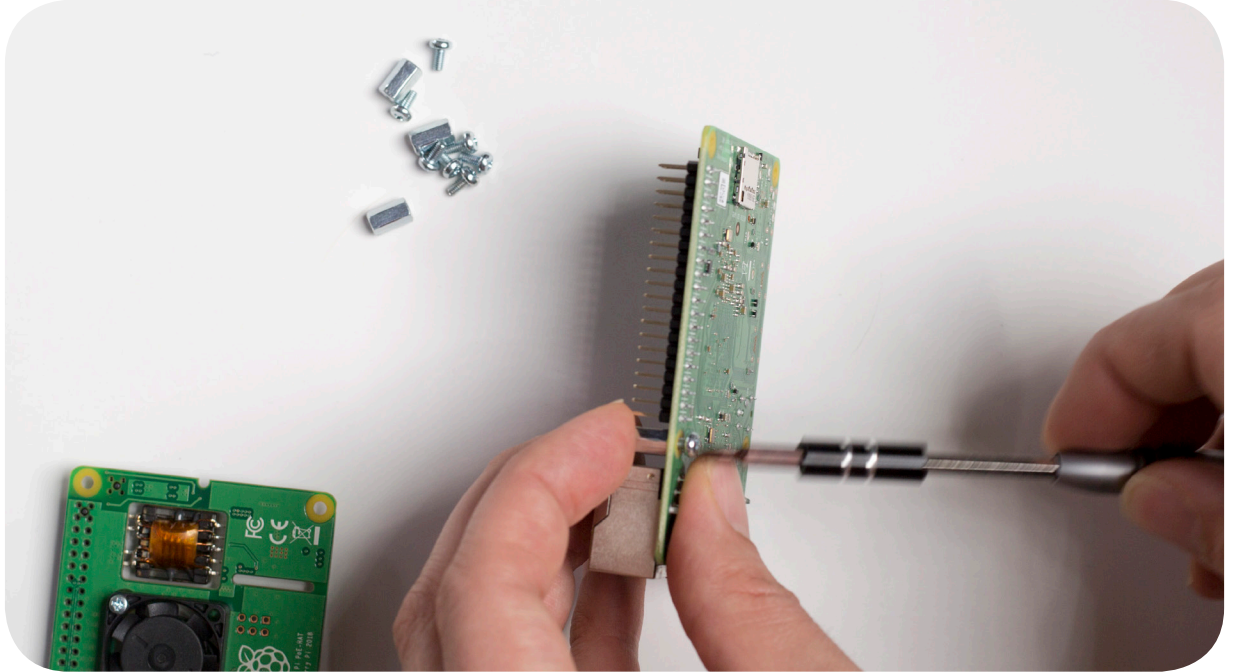
2

The PoE HAT comes with a bag of small screws and stand-offs. Flip the Raspberry Pi over and insert one of the small screws into one of the four holes in the Pi.



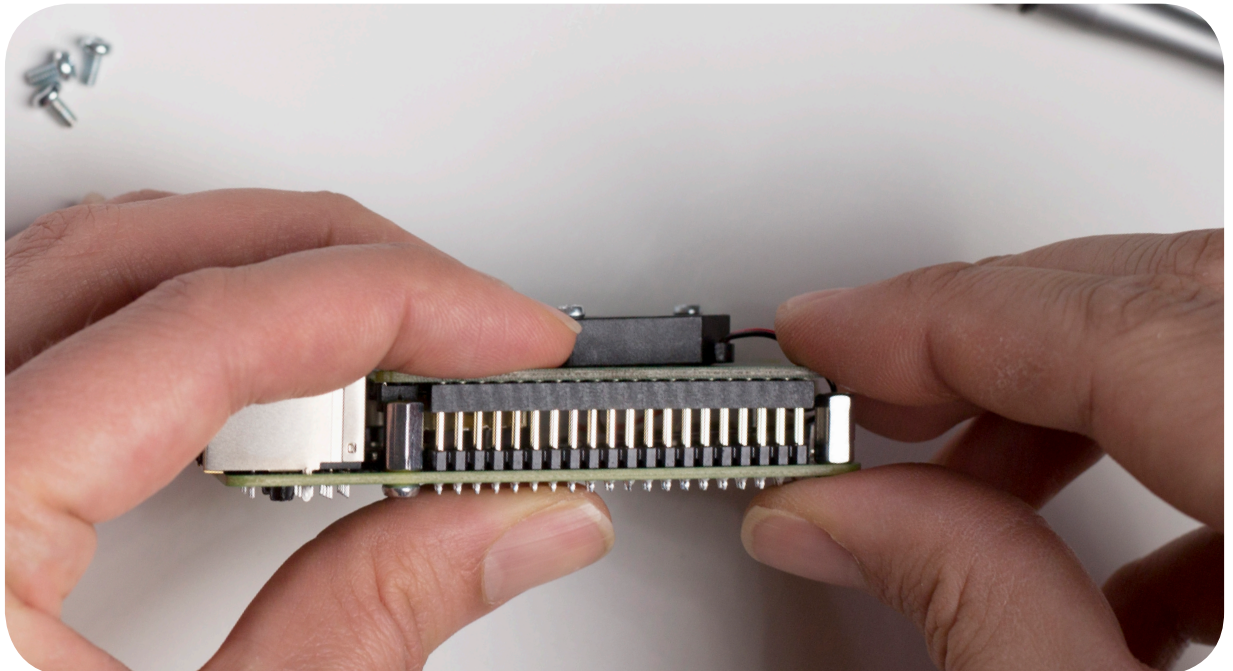
3

Holding the screw with your finger, flip the Raspberry Pi back over and start screwing on one of the stand-offs with your fingers. After a few turns, finish tightening the screw with the screwdriver. Repeat with the three other holes on the Raspberry Pi.



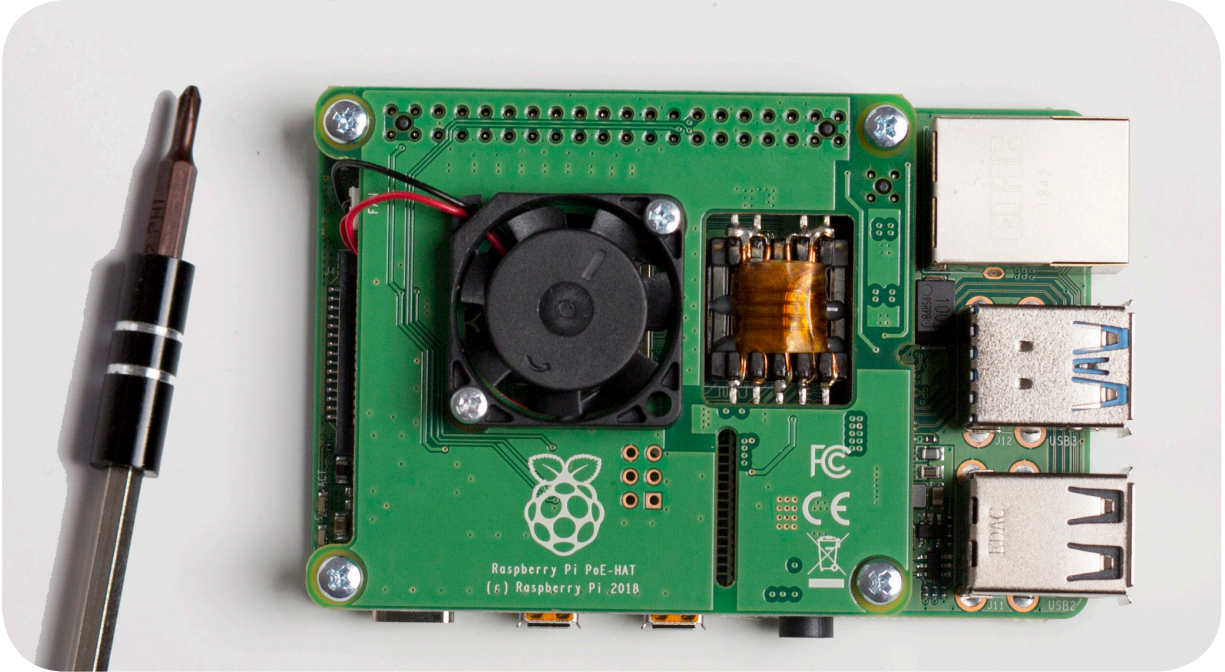
4

Carefully line up the GPIO (metal pins) on the Raspberry Pi with the matching receptacles on the PoE HAT and push down using both hands to apply even pressure.



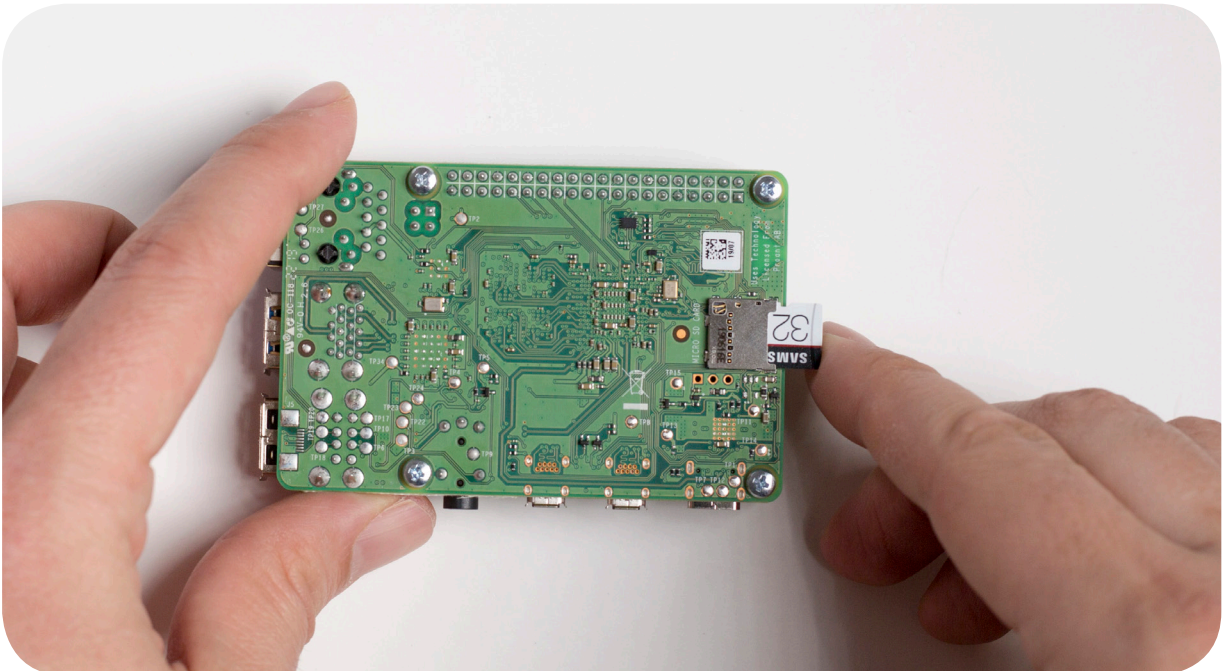
5

Using the screwdriver, screw the remaining four small screws into the four holes on top of the PoE HAT.



6

Flip the Raspberry Pi over and insert the MicroSD Card into the MicroSD Card slot on the Raspberry Pi.

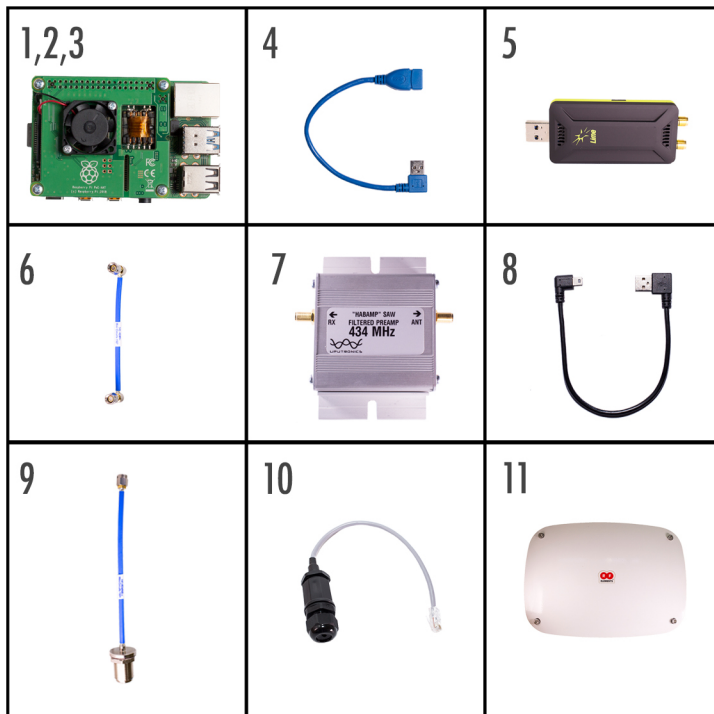


C. ASSEMBLE THE ENCLOSURE

Introduction

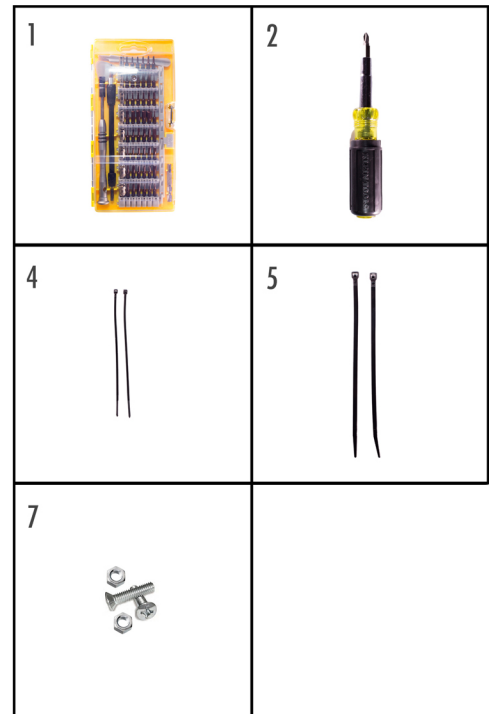
The Enclosure holds the majority of the parts that make up the ground station. In this section, we will secure all the parts inside the enclosure and connect them together. When finished, the enclosure will be ready for installation on the mast.

Parts and Tools Needed in this Section



Parts

1,2,3. Assembled Raspberry Pi 4. USB Extension Cable
 5. Software Defined Radio 6. RF Cable (SDR to LNA)
 7. Low Noise Amplifier 8. USB DC Cable
 9. RF Cable (LNA to Outside) 10. UTP Connector
 11. Enclosure



Tools

1. Precision Screwdriver Set
 2. 11 in 1 Screwdriver
 4. Small Zipties 5. Large Zipties
 7. Machine Screws and Nuts for LNA

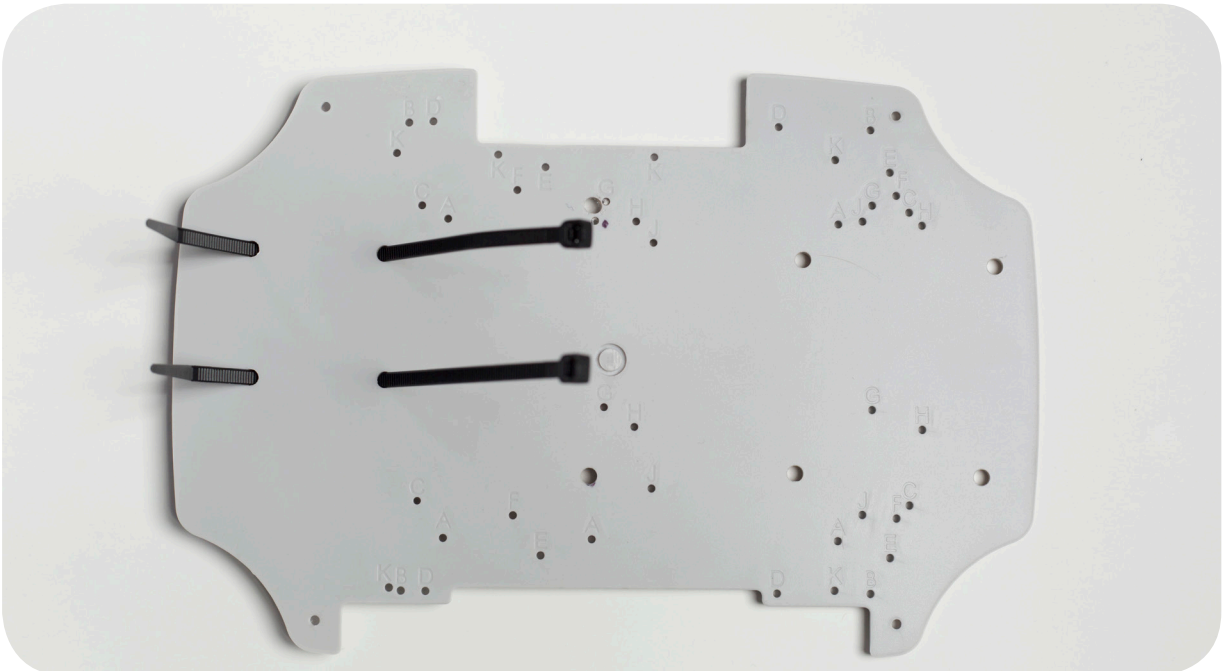
1

Remove the plastic insert from the inside of the Enclosure. Orient the insert in front of you so that the engraved letters are right-side up.



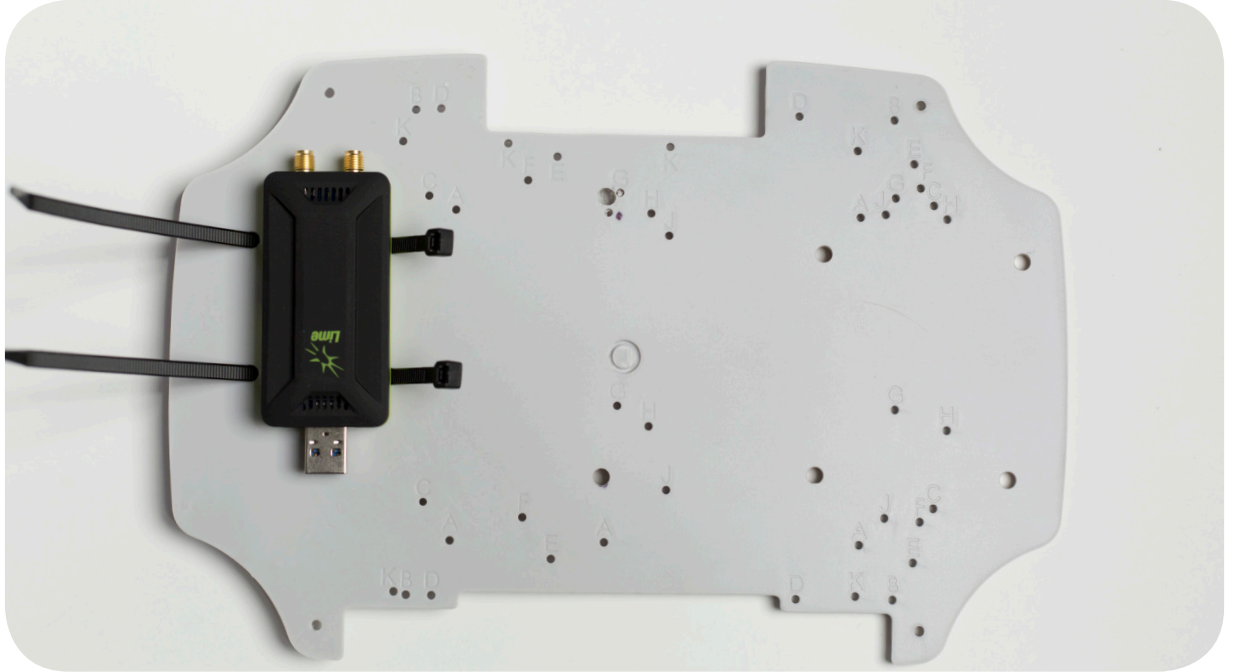
2

Take the two Small Zipties and feed them through the four large holes on the left side of the insert.



3

Remove the Software Defined Radio (SDR) from its packaging and place the SDR with the word Lime upside down.



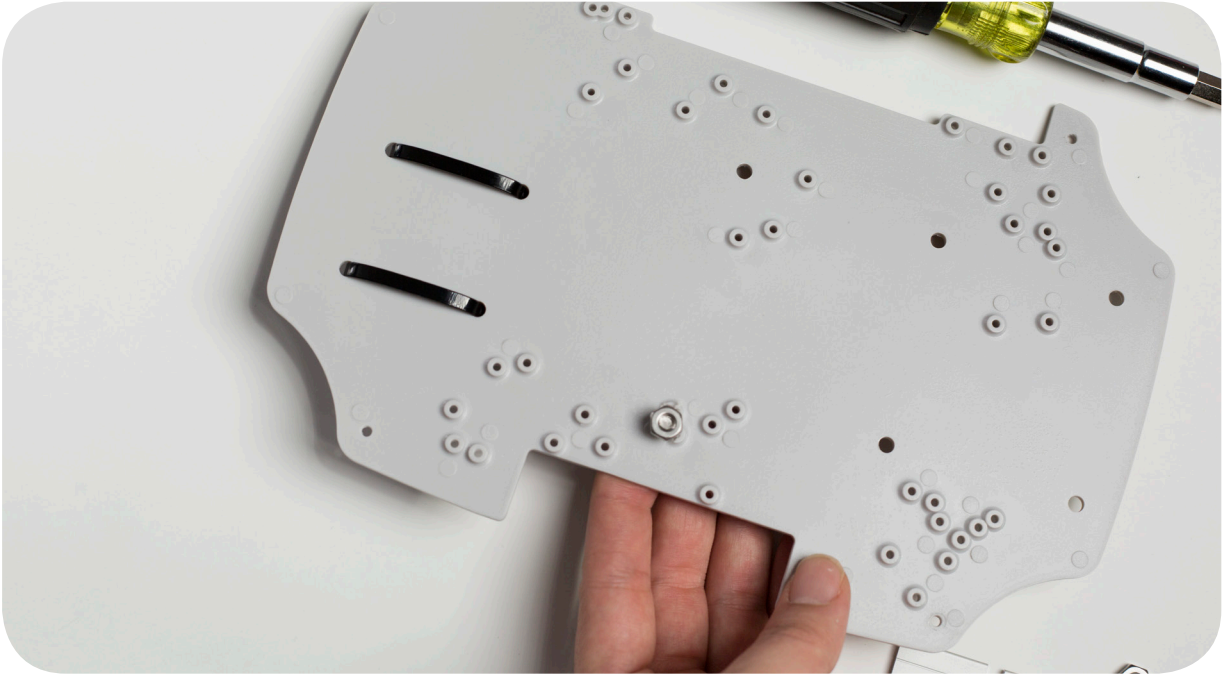
4

Pull the Zipties through their eyes until tight. Snip off the excess with a pair of scissors.



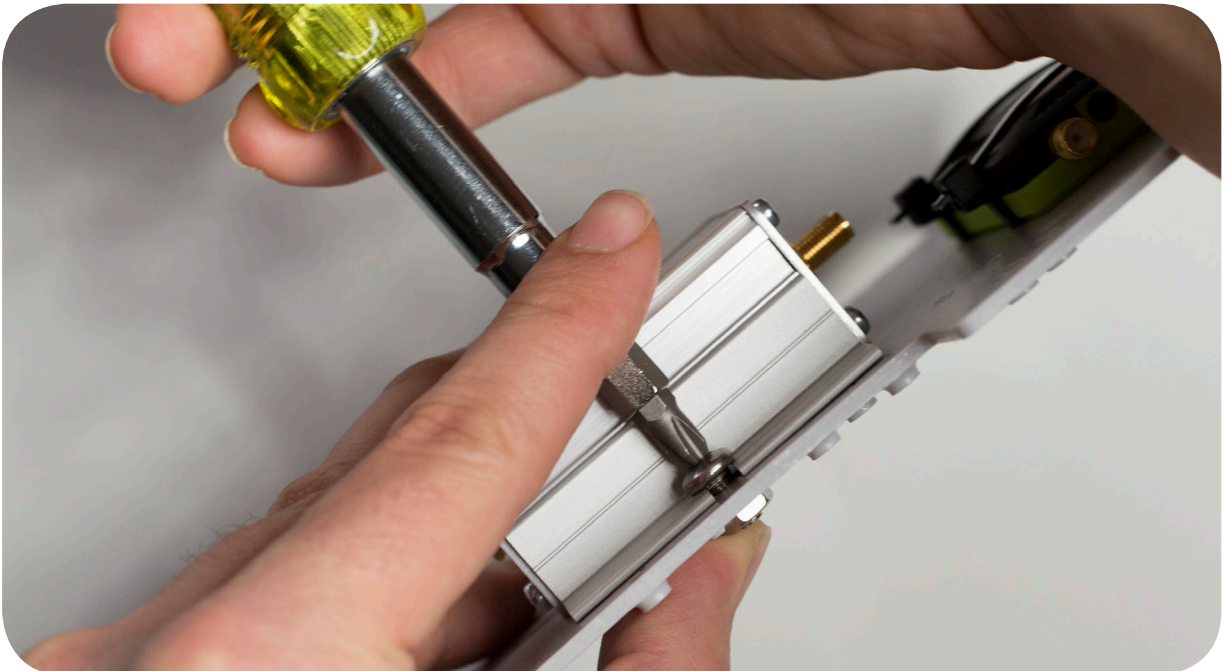
5

Take one of the machine screws (Tool 7) and put it through one of the large holes in the center of the insert. Loosely screw on a matching nut with your fingers on the back of the insert.



6

Fit the groove of the LNA bracket under the cap of the machine screw. While holding the nut on the back with one hand, use the 11-in-1 Screwdriver with a Phillips head to tighten the machine screw.



7

Repeat steps 5 and 6 for the other machine screw and nut on the bottom bracket of the LNA.



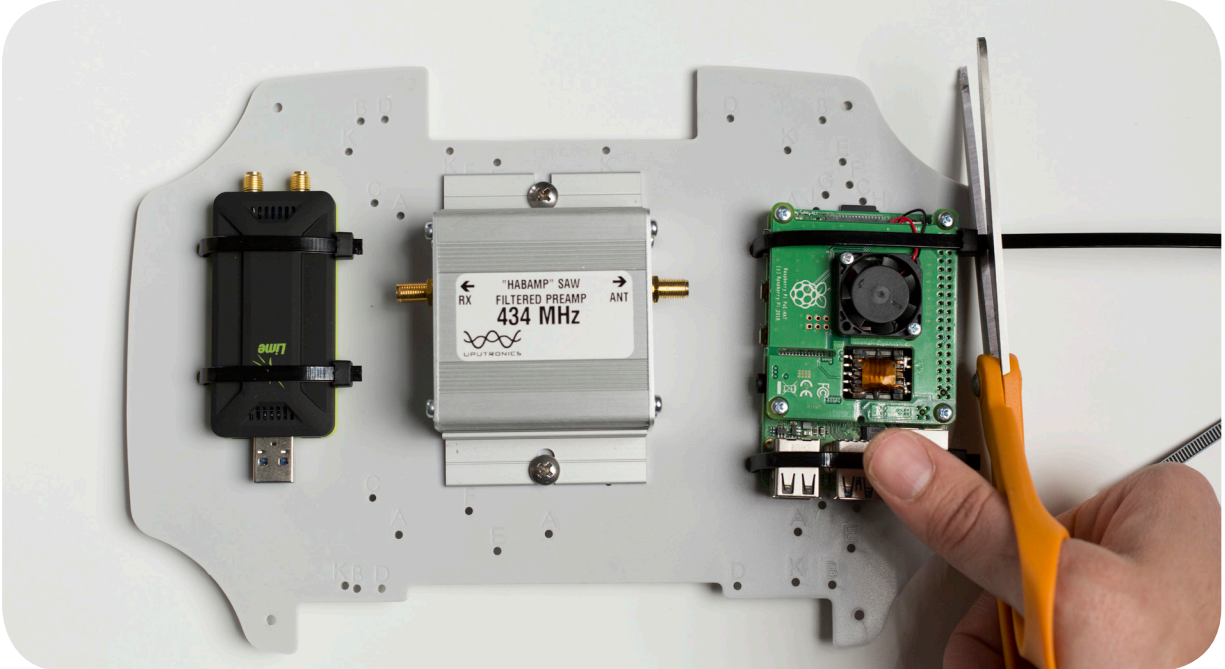
8

Feed the Large Zipties through the four large holes on the right side of the insert. Place the Raspberry Pi with the USB ports at the bottom.



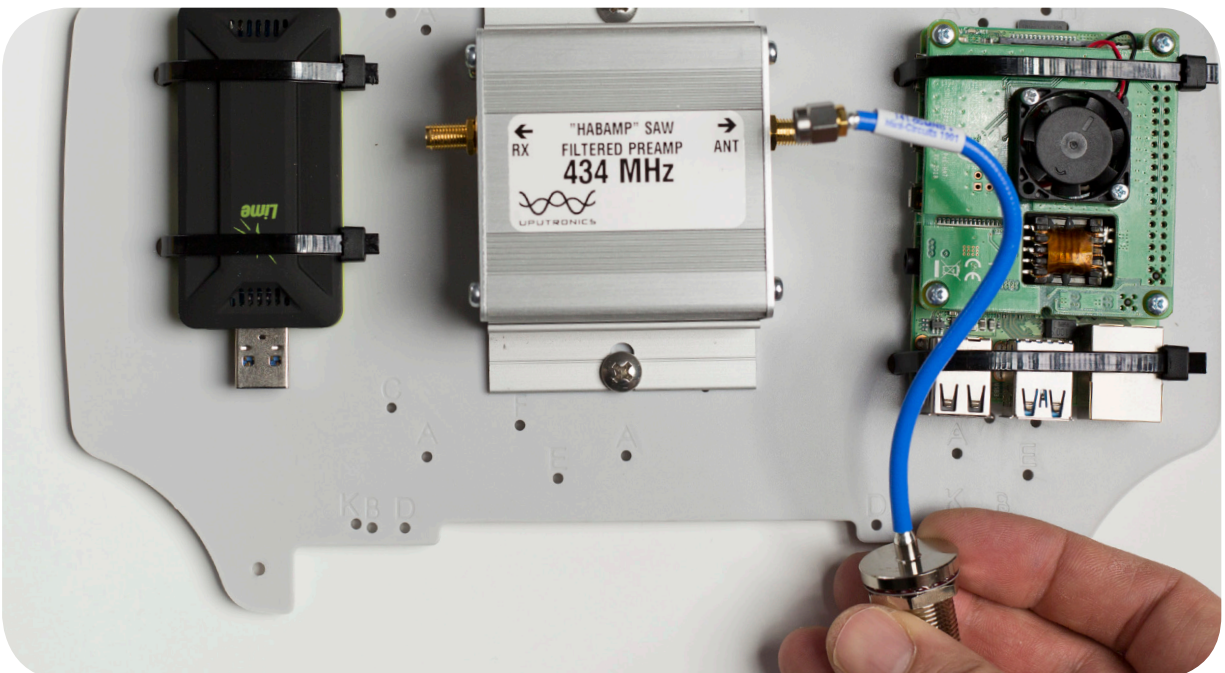
9

Pull the Zipties through their eyes until tight and cut the excess with a pair of scissors.



10

Take the RF Cable (LNA to Outside) and carefully bend it into a question mark shape. Make the bend in the middle of the cable as far from either connector as possible.



11

Holding the RF cable with one hand so that it does not twist, screw in the smaller connector to the right side of the LNA marked ANT (short for Antenna) with your other hand.



12

Take the RF Cable (SDR to LNA) and bend it into a question mark shape. Make the bend in the middle of the cable as far from either connector as possible, and do not twist the cable.



13

Holding the RF cable with one hand so that it does not twist, screw in one connector to the left SMA terminal (RX) on the Lime. Screw in the other connector to the left side of the LNA marked RX (short for Receive).



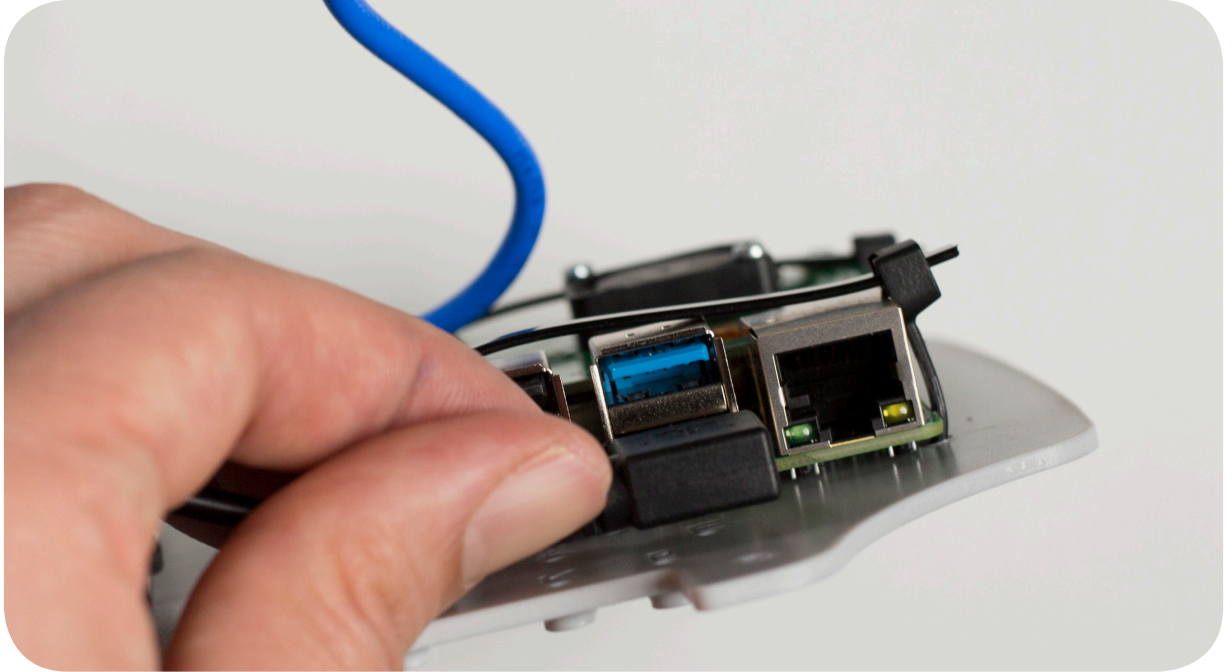
14

Take the USB DC Cable and connect the mini USB end to the mini USB port on the left side of the LNA.



15

Connect the full-size USB end to the bottom USB 3.0 (blue) port on the Raspberry Pi. You might need to carefully push the RF cable out of the way.



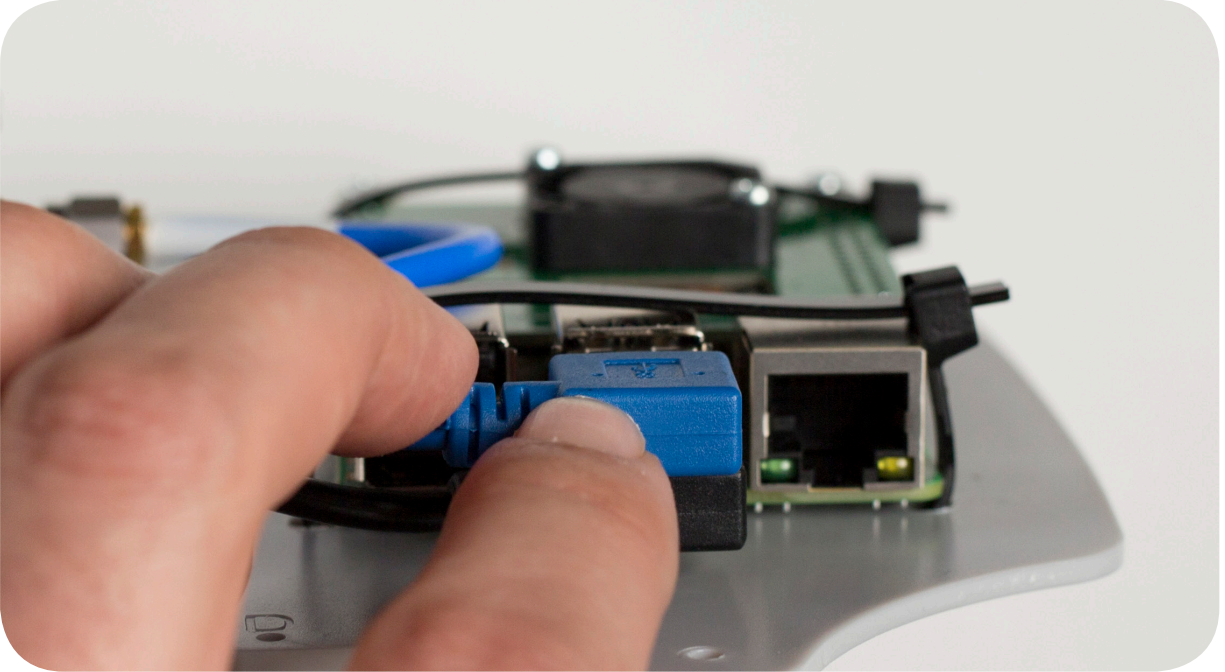
16

Take the USB Extension Cable and connect the straight end to the SDR.



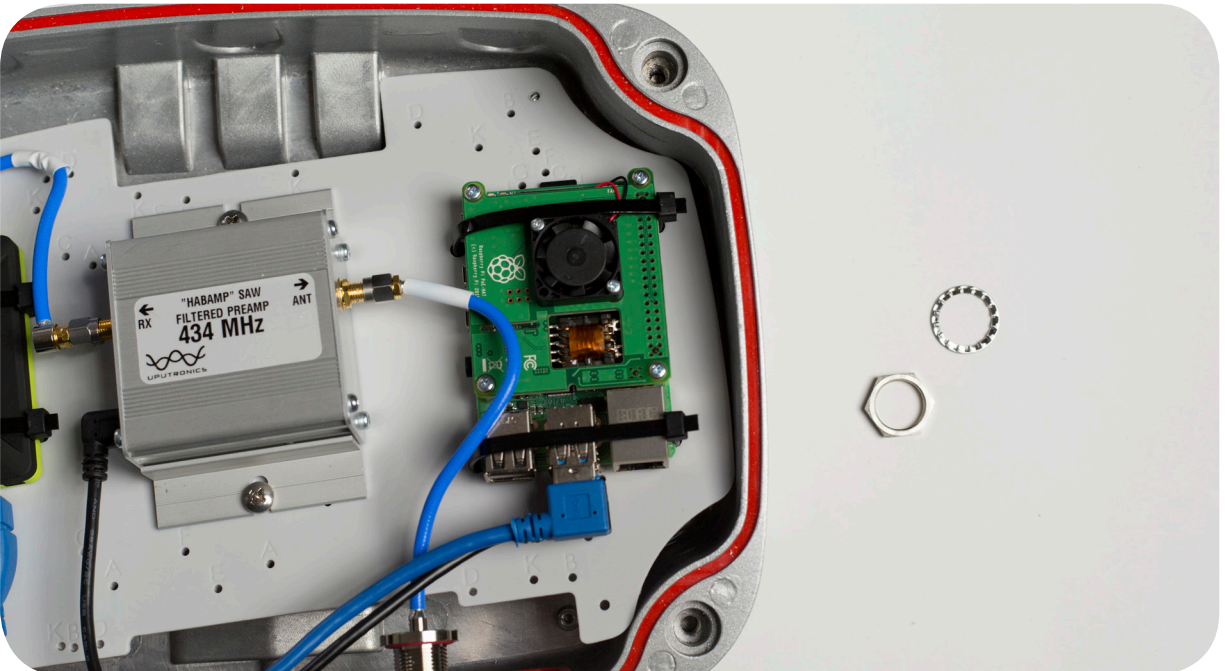
17

Connect the angled end of the USB Extension Cable to the top USB 3.0 (blue) port on the Raspberry Pi.



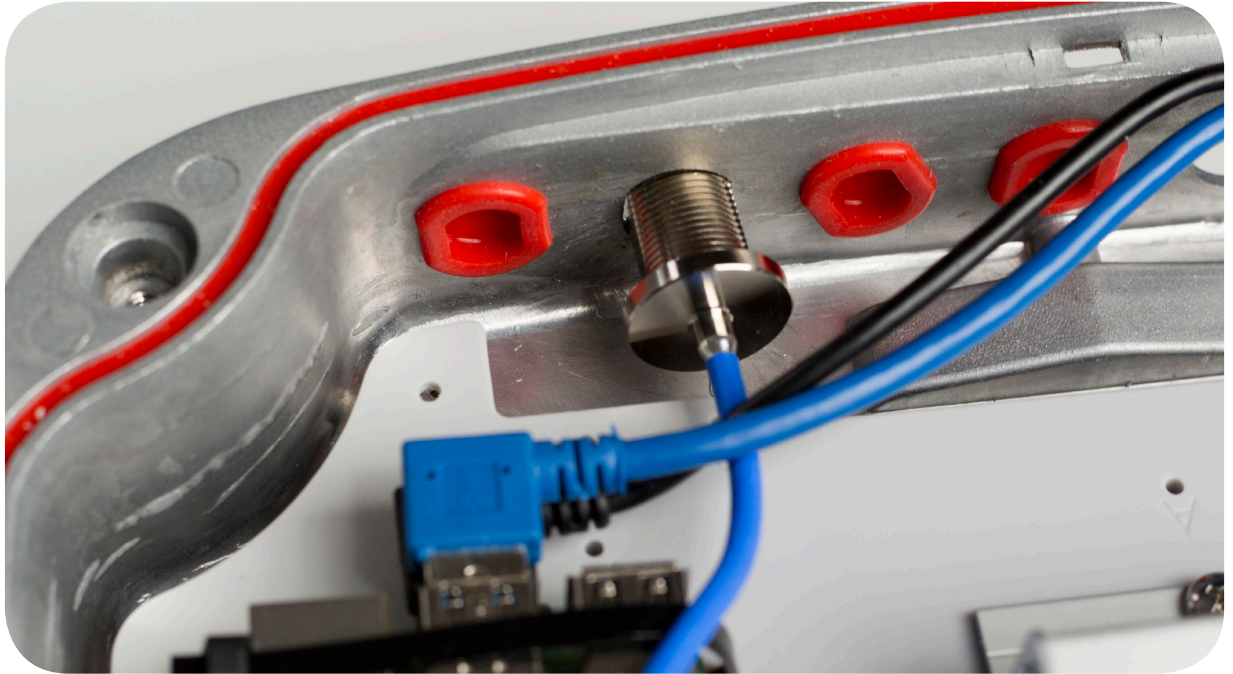
18

Remove the metal washer and retaining nut from the Type N connector on the RF Cable (LNA to Outside) and set them aside.



19

Place the insert into the Enclosure with the top off. Line up the Type N Connector on the RF Cable (LNA to Outside) with the second hole on the bottom of the Enclosure and carefully push it through with your thumb.



20

Working now on the outside of the Enclosure. Place the metal washer over the Type N Connector.



21

While holding the Type N connector flush to the metal of the inside of the Enclosure, screw on the retaining nut as tight as you can with your fingers.



22

Find the cap for the Type N connector and cap it until ready to install the station.



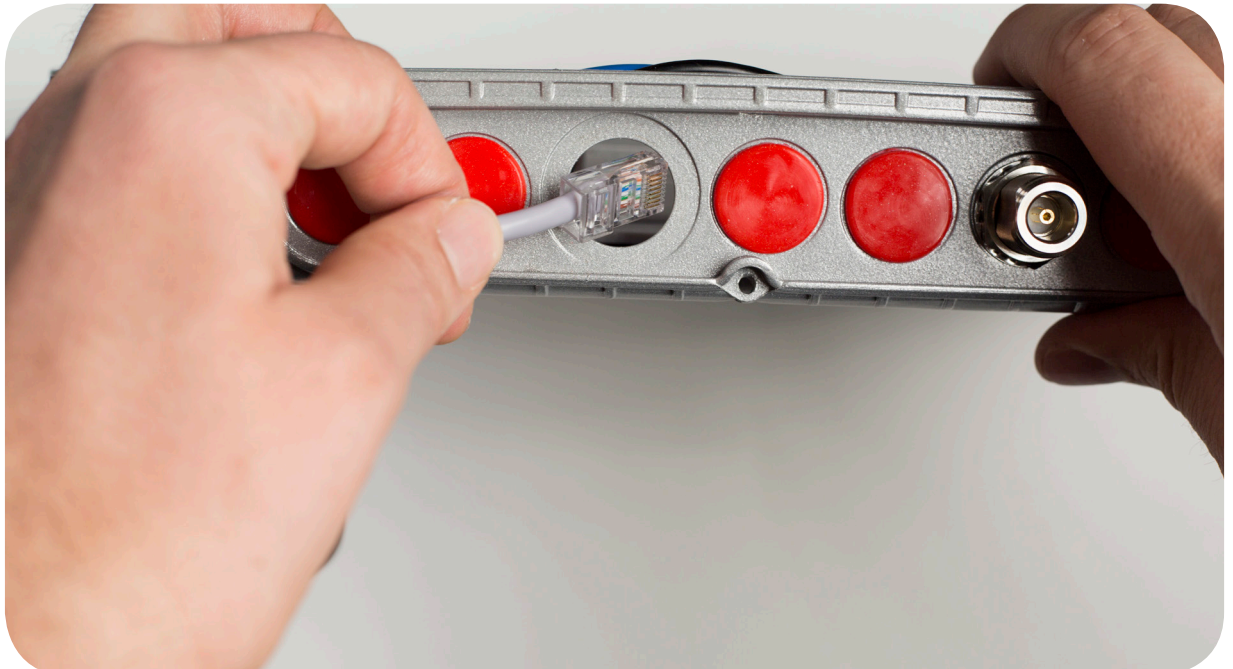
23

Find the UTP Enclosure Connector. Unscrew the black plastic retaining nut and set it aside.



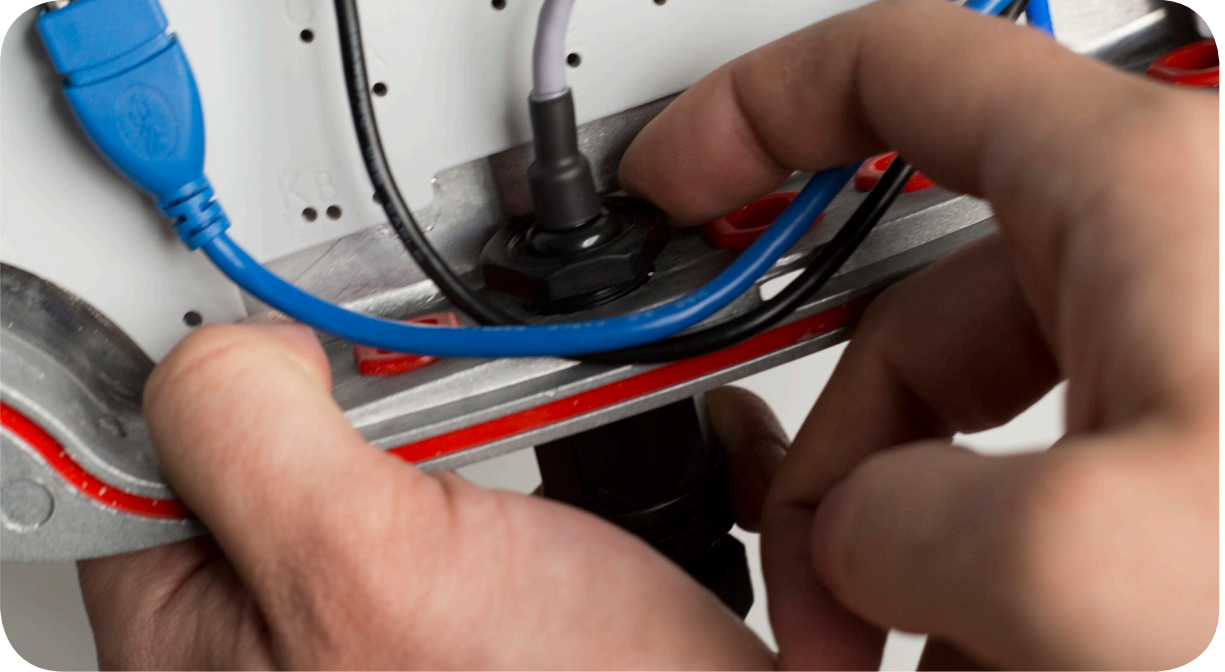
24

Thread the Ethernet jack through the large hole on the bottom of the enclosure, and push the connector all the way in.



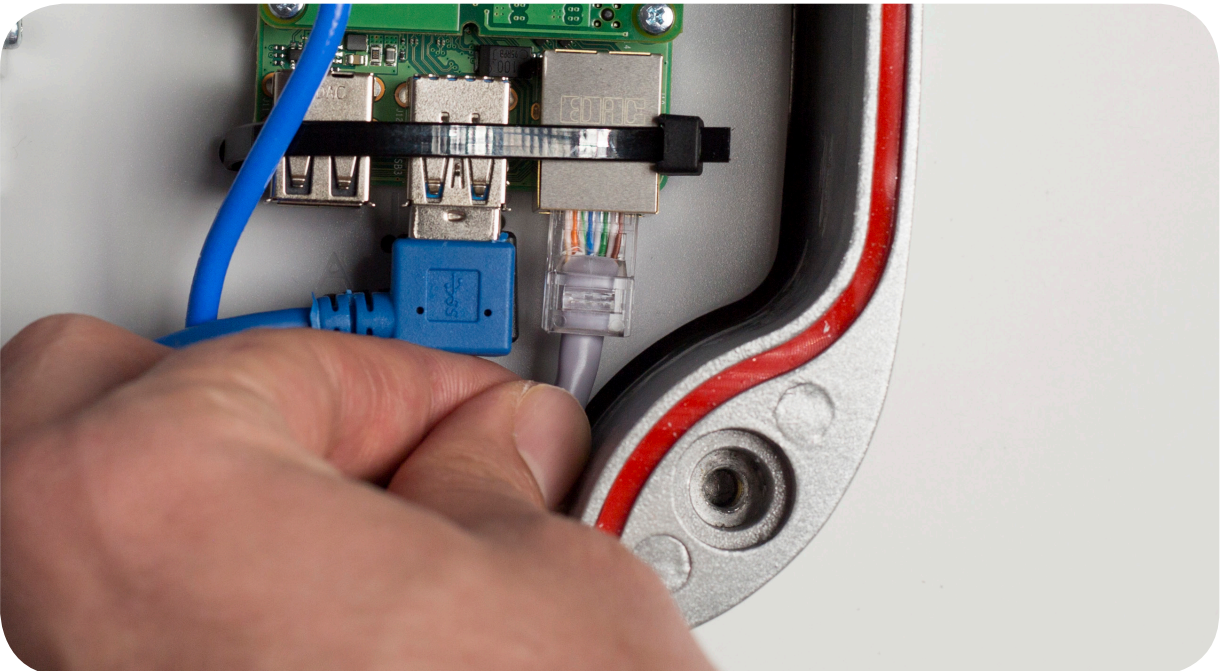
25

Take the black plastic retaining nut you set aside and thread it back on finger-tight.



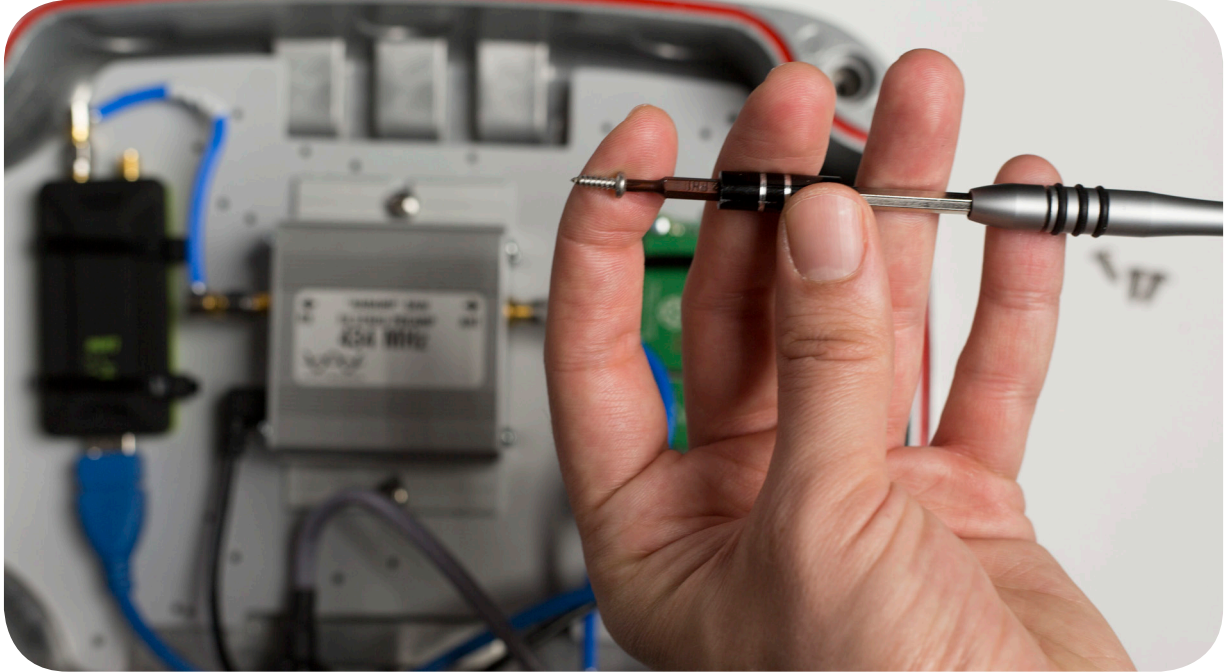
26

Connect the Ethernet jack to the Ethernet port on the Raspberry Pi.



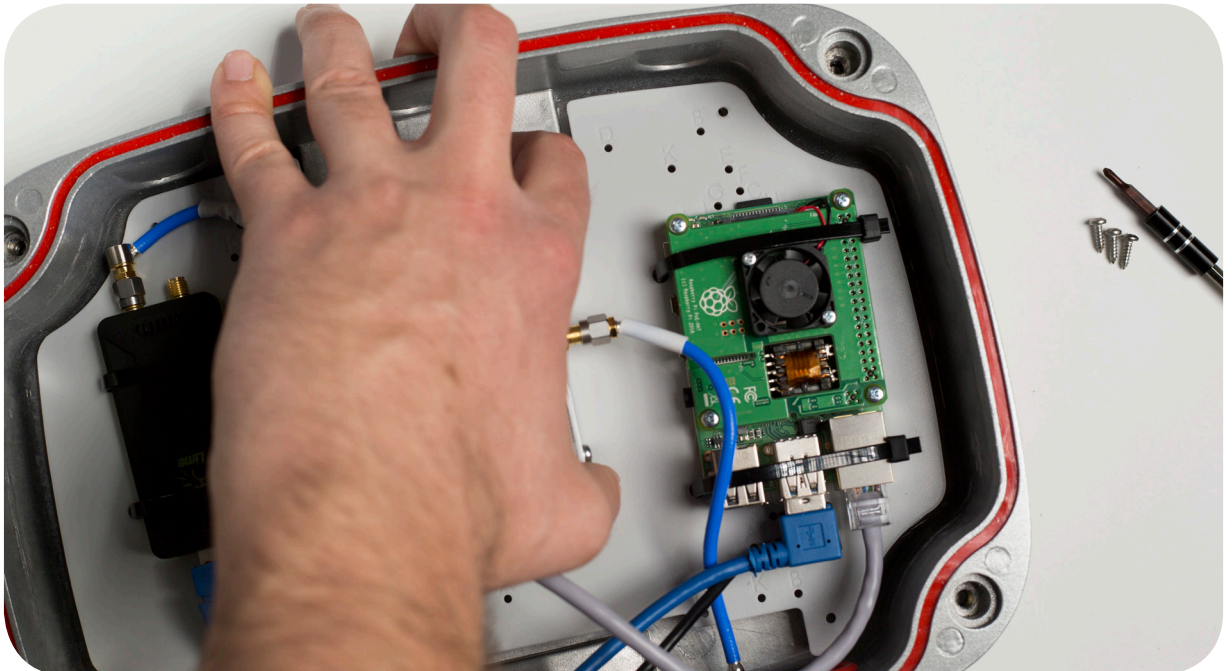
27

Find the Precision Screwdriver Set with a small Phillips head, and the Ziploc bag of metal screws from the Enclosure (bag labeled insert screws).



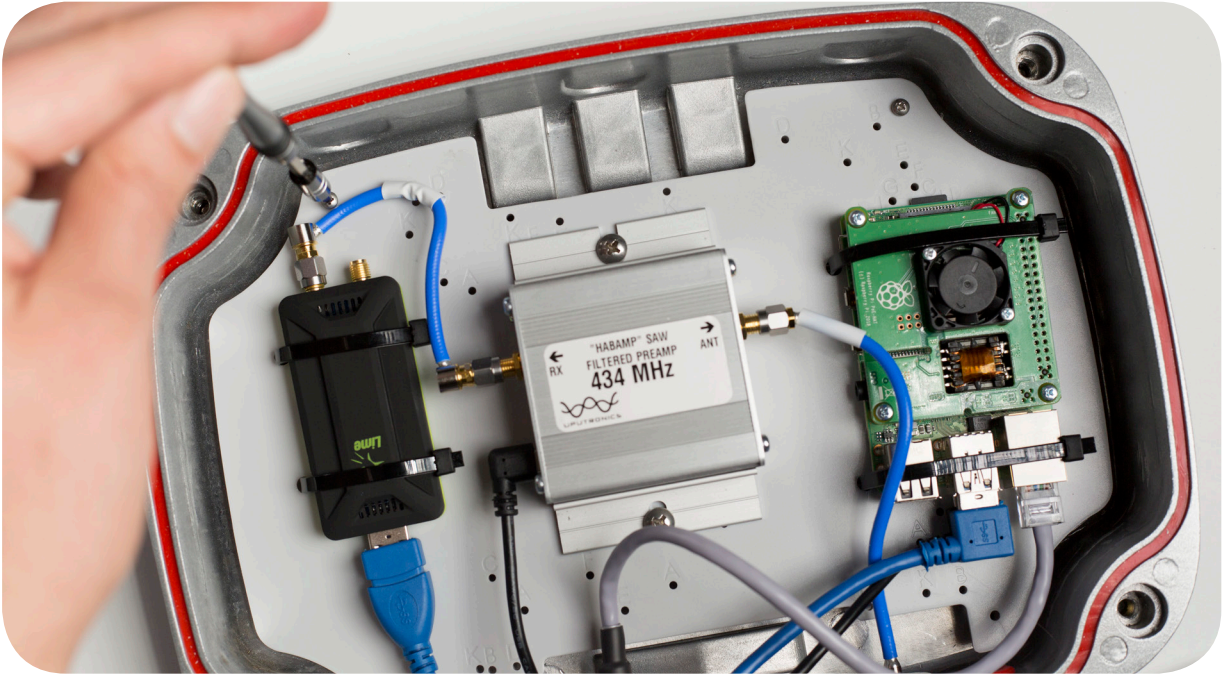
28

Line up the plastic insert with the bottom of the Enclosure so that the holes on the corners of the insert line up with the holes in the Enclosure.



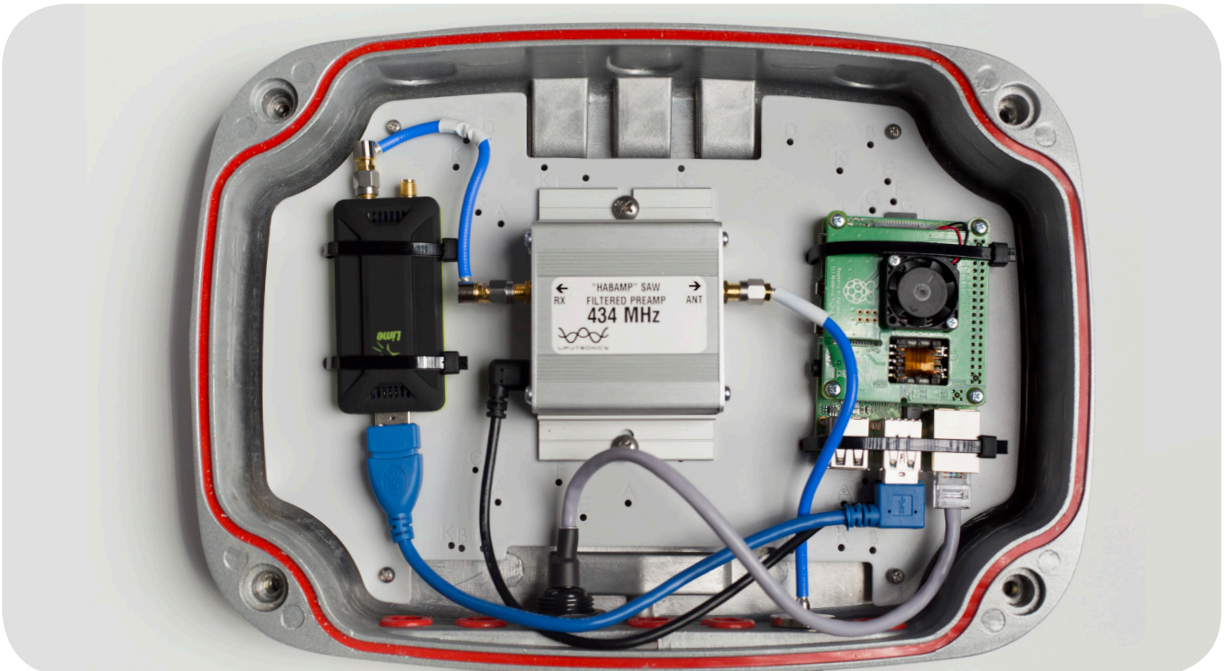
29

Screw in the four small screws into the four holes in the corners of the plastic insert.



30

The inside of the Enclosure is now complete and should look like this:



31

Find the top of the Enclosure and the Allen wrench that was in the plastic bag inside the Enclosure. Screw on the top of the Enclosure with the Allen wrench.

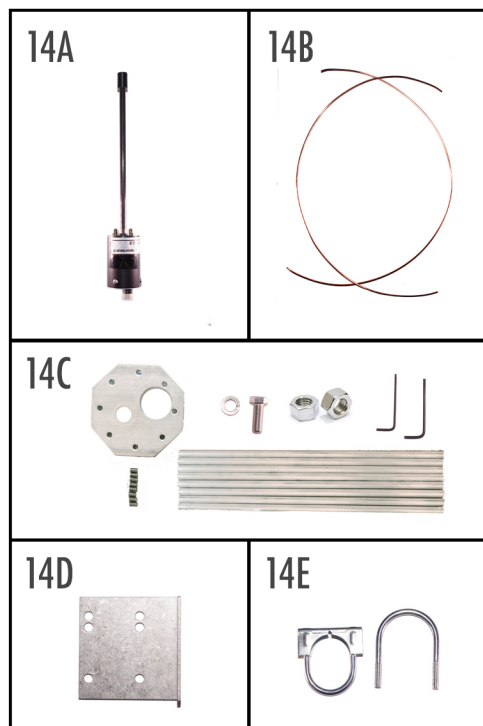


D. ASSEMBLE THE ANTENNA

Introduction

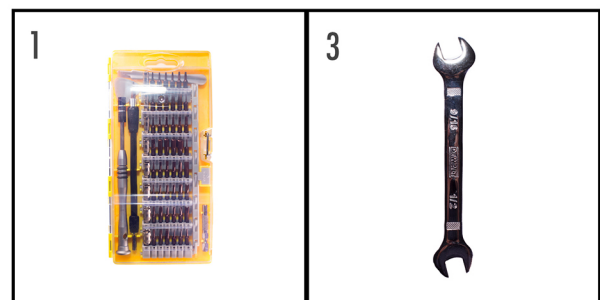
The antenna is a critical component of the ground station as it receives the radio communications from the satellites passing overhead. This antenna is an omnidirectional UHF antenna that receives in the 70cm band (400-470MHz). Amateur satellites are allocated a small portion of this range from 435-438 MHz and many transmit to Earth in this frequency range. The antenna should be assembled indoors before being installed on top of the mast on the library's roof. Assembly of the antenna should not be difficult, but please take care when handling the copper loops as their ends are somewhat sharp, and you will be bending them to create circular loops.

Parts and Tools Needed in this Section



Parts

14A. Balun 14B. Copper Loops
 14C. Radial Plate, Small Set Screws (8),
 Radials (8), Bolt, Washer, Nuts, Allen Wrenches
 14D. L Plate 14E. U-bolts (for mounting)

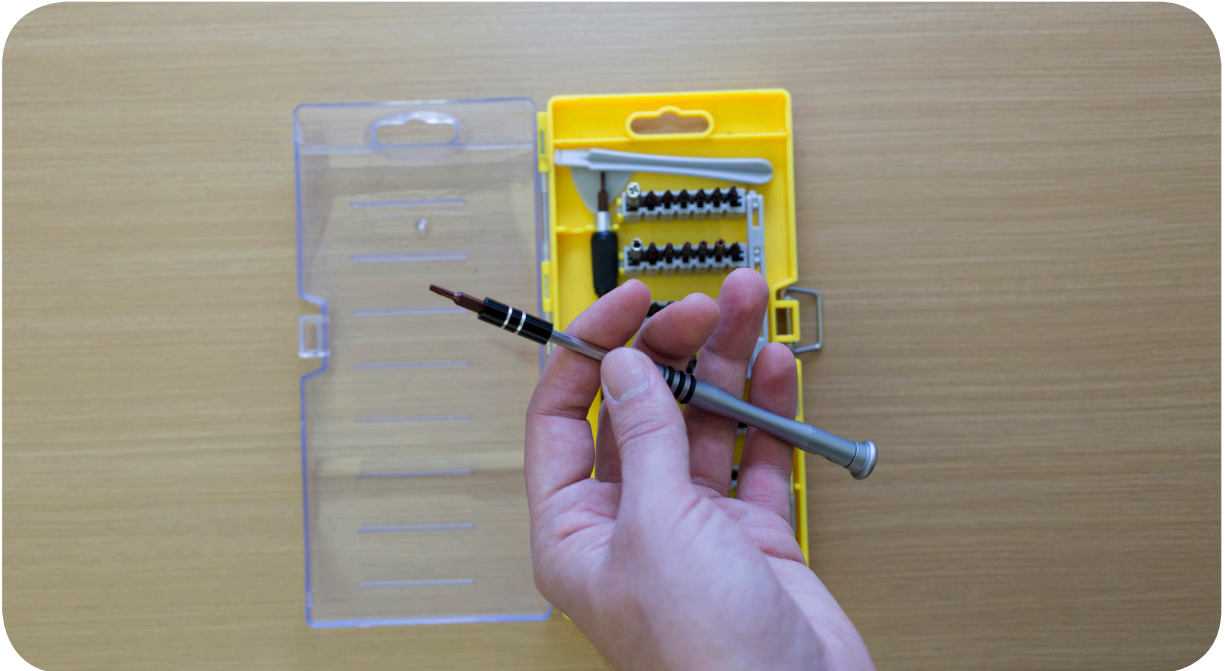


Tools

1. Precision Screwdriver Set
 3. 1/2 & 9/16 End Wrench

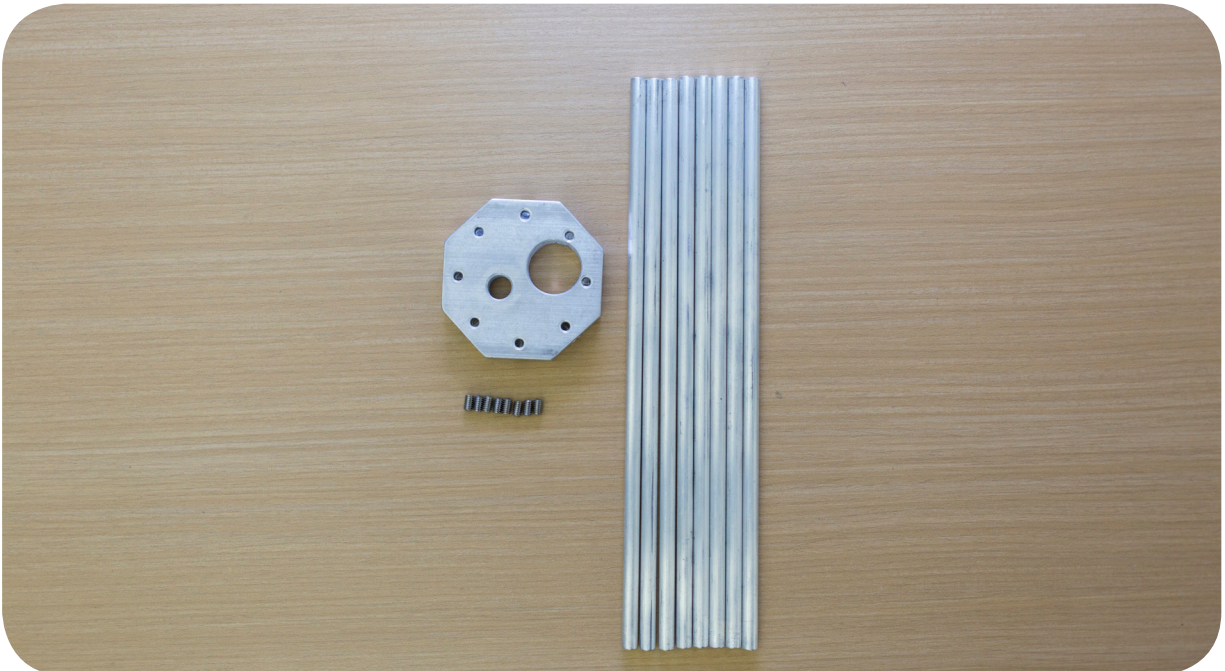
1

Open the Precision Screwdriver Set and affix the 2mm Hex bit (3rd row, 6th in from left) in the screwdriver handle.



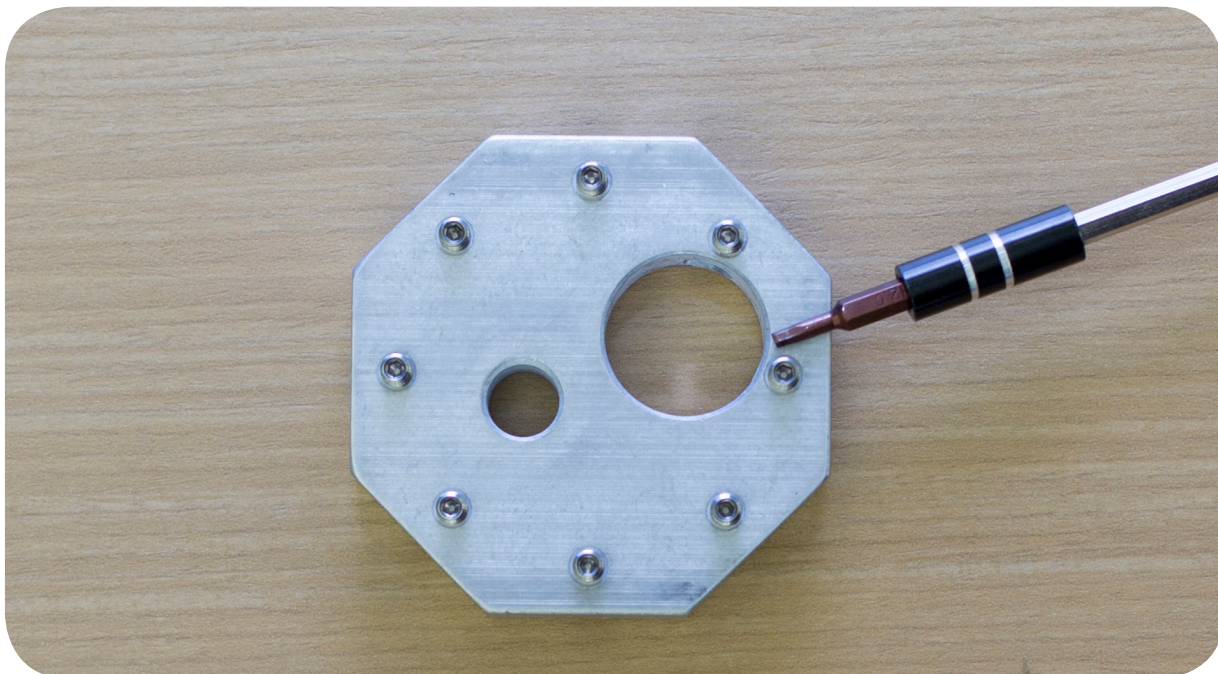
2

Remove the contents of the bag marked 14C and separate out the following which makes up the antenna's reflector:
8 radials (metal poles), 1 radial plate (octagon-shaped piece of metal),
8 small set screws. Set aside the rest of the contents of the bag.



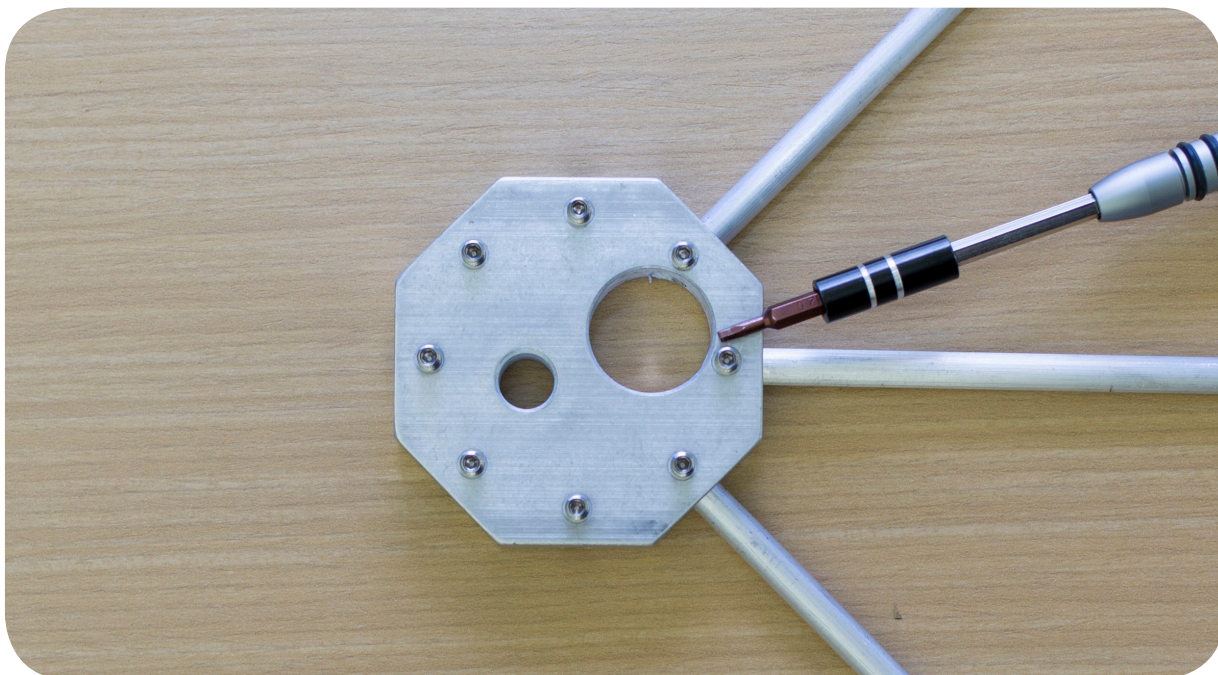
3

Take a set screw, fit it on to the screwdriver and give it one turn into a hole on the radial plate. Do not tighten all the way yet, just enough to get it started. Repeat for all eight set screws.



4

One at a time, take one of the radials and push it into one of the holes on the sides of the radial plate. Tighten down the appropriate set screw with the screwdriver until the radial is secure. Repeat for all eight radials. Keep the large hole in the radial plate clear of obstructions. Set assembled reflector aside.



5

Find the balun (14A) and the curved copper loops (14B), and the larger Allen wrench in package 14C.



6

Remove the wrapping from the balun. Loosen the set screws on top of the balun with the appropriate Allen wrench from the 14C bag.



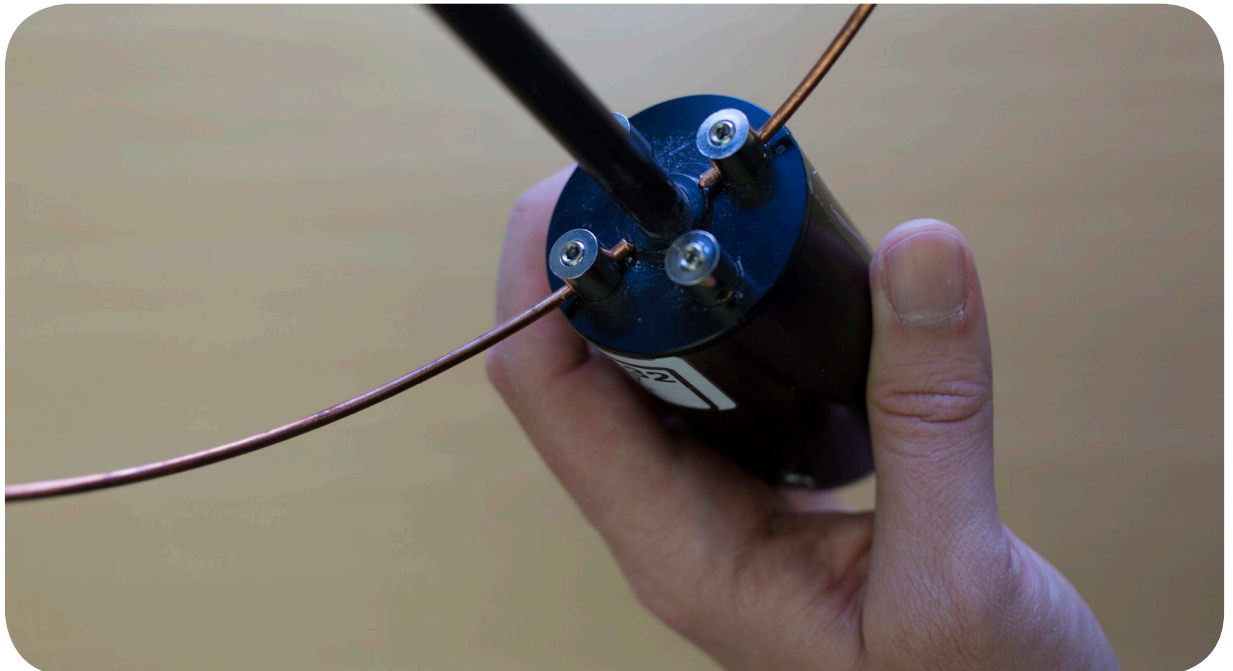
7

Take one of the copper loops and thread it through one of the holes at the top of the rod.



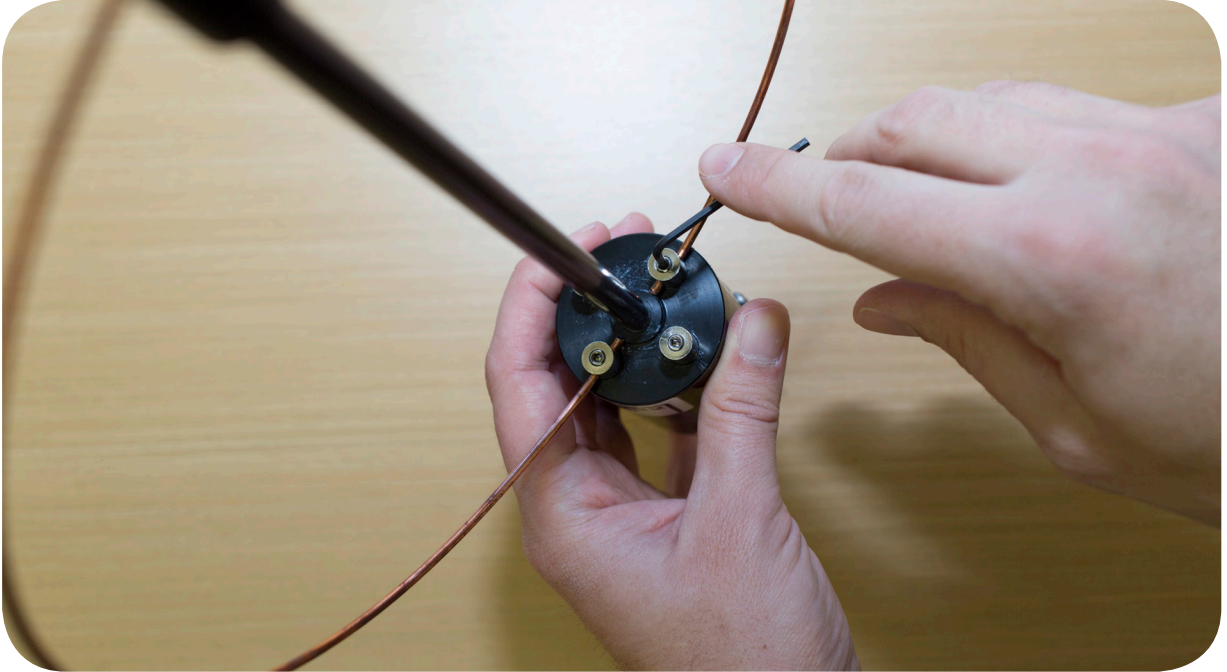
8

Carefully take the two ends of the copper loop and push them into the terminals on the top of the balun until they are flush with the delrin washer at the base of the rod. Even out the loop at the top of the rod as necessary so that it forms an even circle.



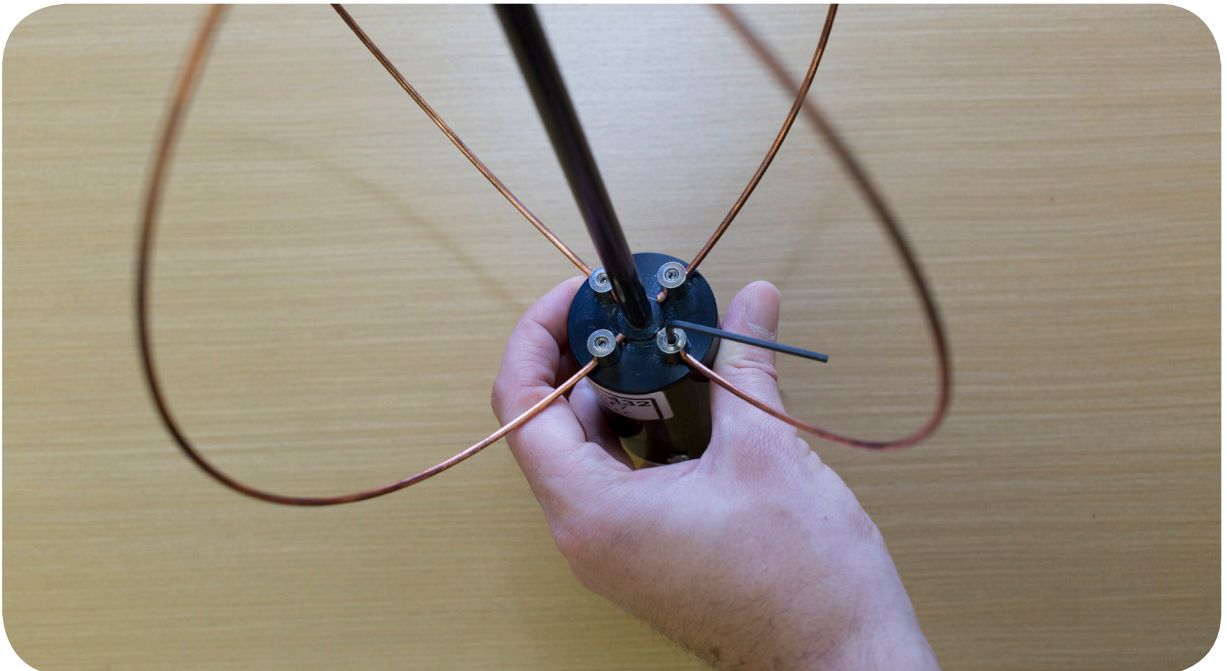
9

Tighten the set screws with the Allen wrench.



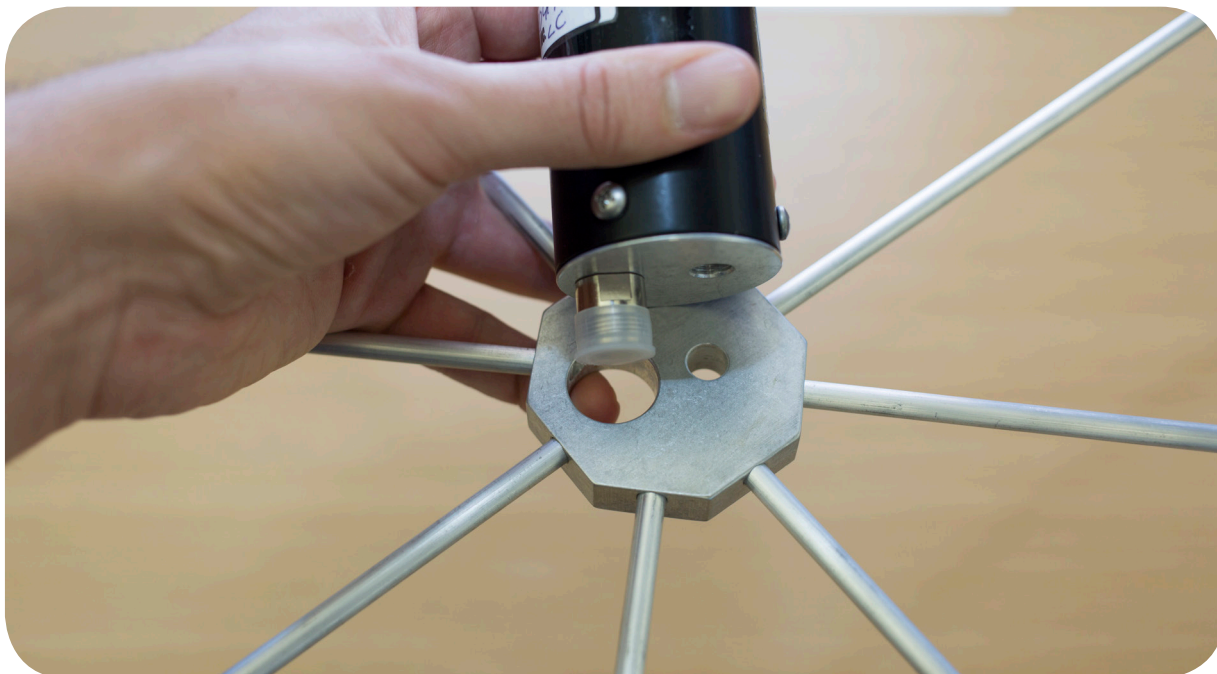
10

Repeat steps 8-10 with the other copper loop.



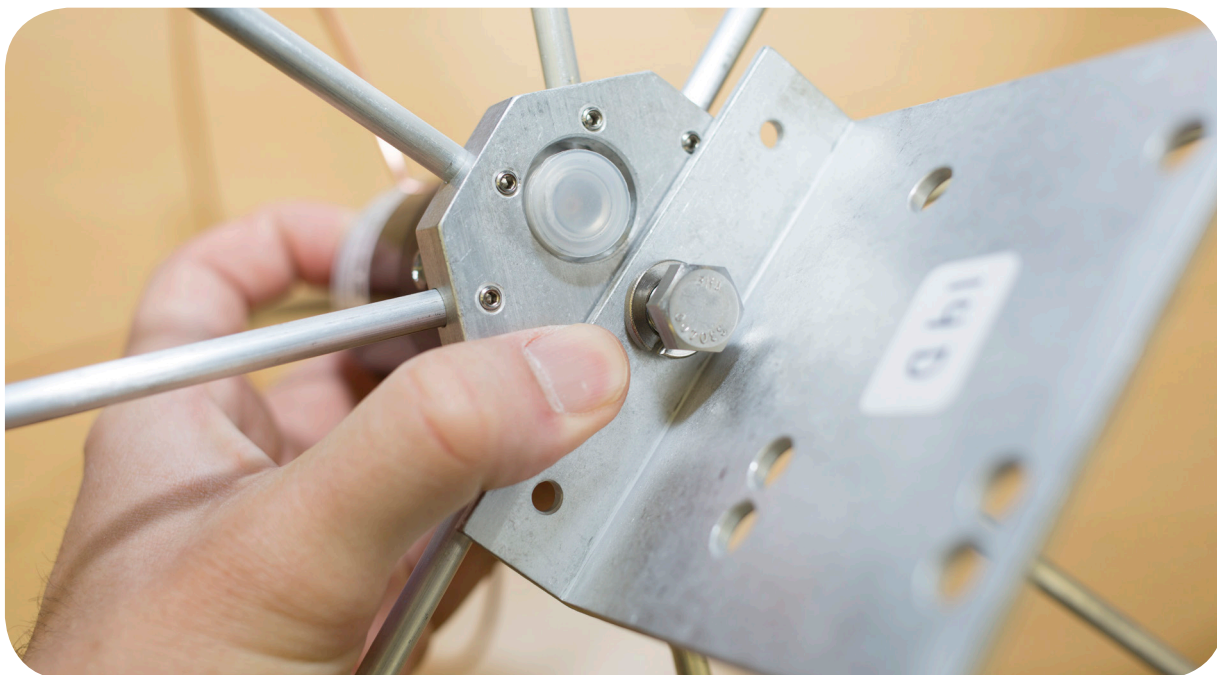
11

Gather together all the antenna parts including those already assembled. Find the L plate (14D), the large bolt and washer from the 14C bag, and the End Wrench (Tool 3), and place them on the table in front of you. Fit the balun into the smooth side of the radial plate, lining up the Type N connector to fit through the larger hole.



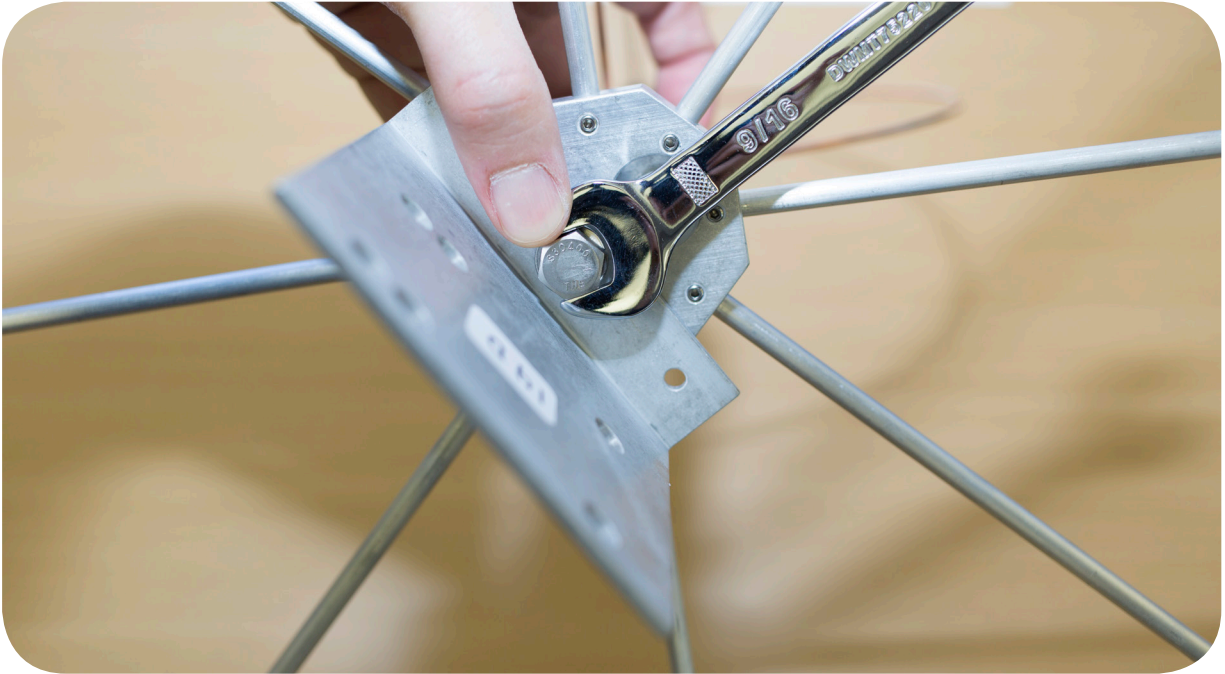
12

Carefully flip the whole thing to one side, and line up the center hole on the L plate with the smaller hole on the bottom of the balun. Put the washer on the large bolt, insert the bolt into the lineup holes, and give a few turns with your free hand to secure it.



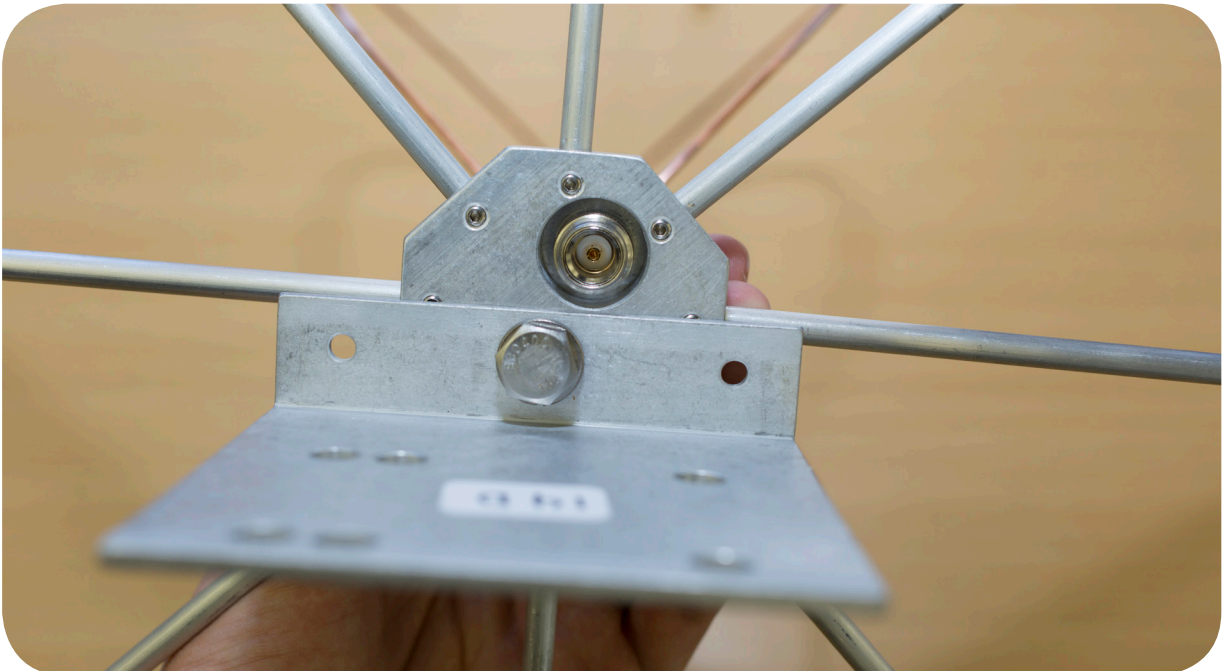
13

Tighten the bolt further with the 9/16 side of the End Wrench.



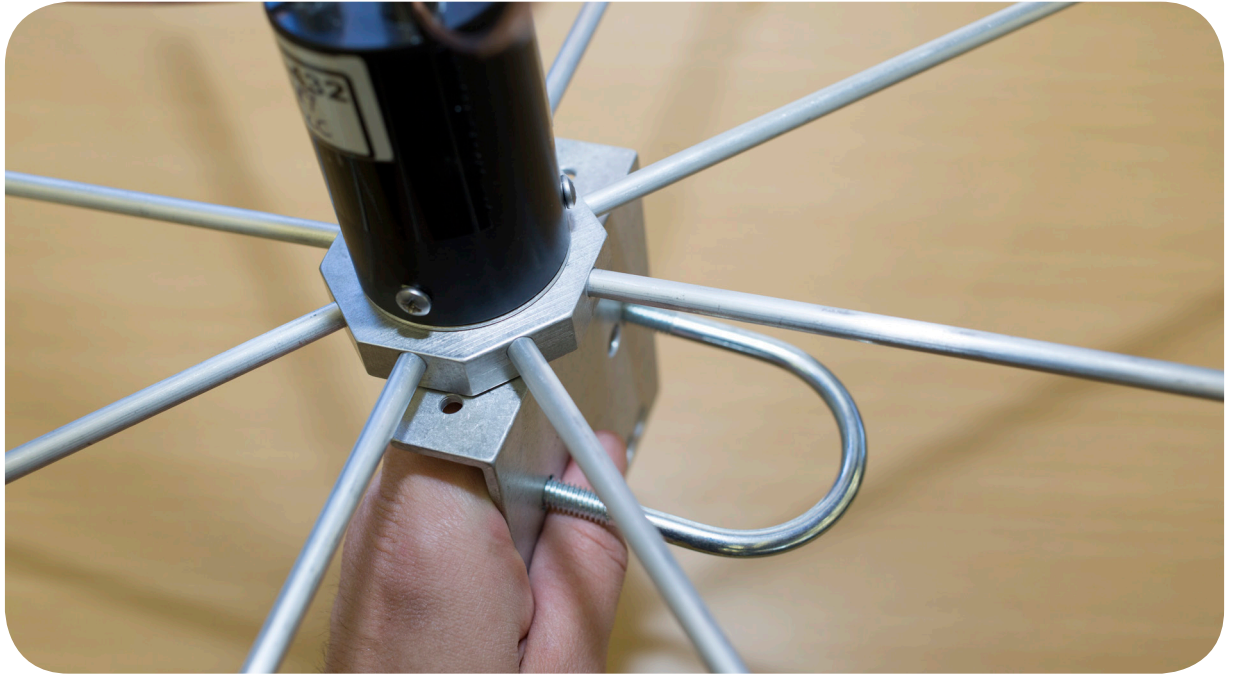
14

When you are close to having the whole thing tight, adjust so that the Type N connector is centered in the hole before final tightening.



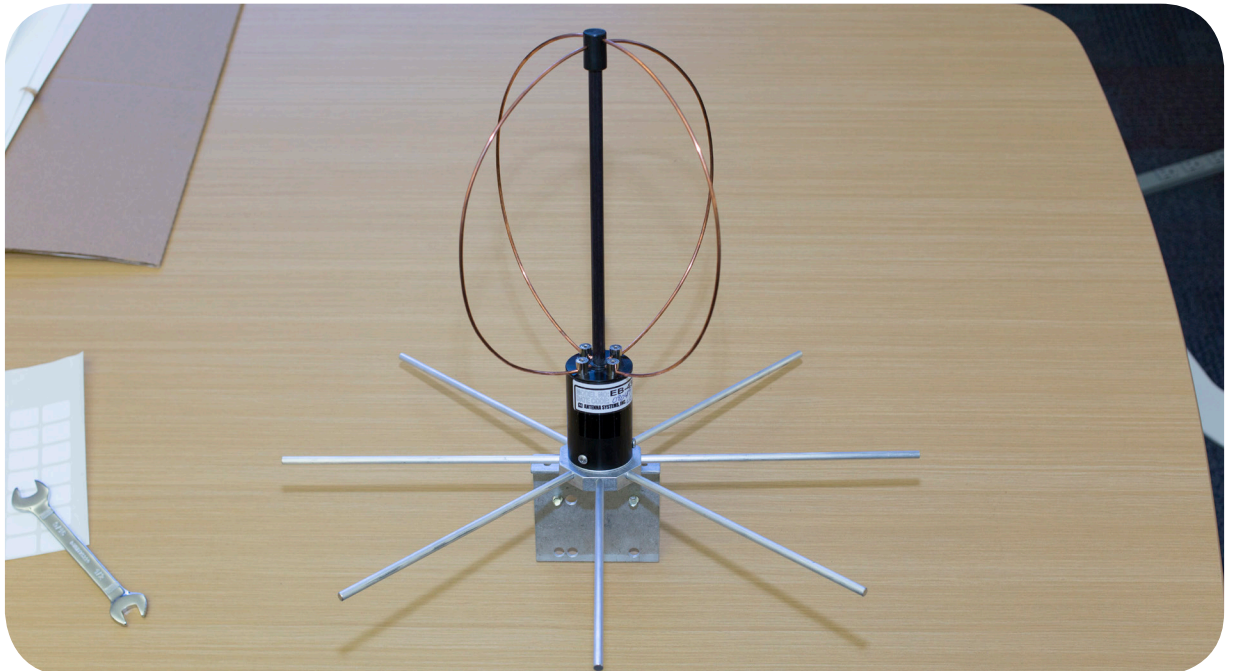
15

Keep the U-bolts, nuts, and other hardware with the assembled antenna as they will be needed when the antenna is installed on the mast.



16

The completed antenna will look like this:



E. PREPARE FOR INSTALLATION

Introduction

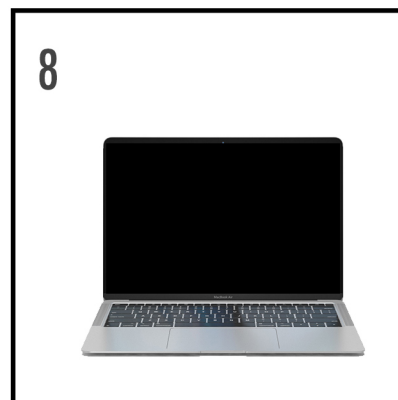
Now that most of the components of the ground station are built, we need to prepare to install them in their permanent location. The most suitable location is likely the roof of the library as we want the antenna to be as high and free from possible interference as possible. There may already be a suitable pole or pipe on your library's roof that can function as the Mast (Part 12) for the ground station. If not, we will need to work with you to install a Mast before installing the ground station. The other preparatory steps are to find out how to run an ethernet cable from the ground station on the roof to inside the library where it can be plugged into a dedicated Ethernet port. In addition to requiring one Ethernet port inside the library, the station also requires one grounded power outlet to plug in the Power Over Ethernet Injector. You may also need help from your library's IT staff starting at step 11.

Parts and Tools Needed in this Section



Parts

- 1-11. Assembled Enclosure
- 15. POE Injector
- 16. Ethernet Cables



Tools

- 8. MacBook

1

Find a pipe or pole to serve as a Mast or install one on your library's roof. If using an existing pipe, measure the diameter of the pipe, so that we can order suitable mounting hardware.



2

Once the physical install location of the ground station is known, we need to figure out where the longer Ethernet cable will enter the building to get to the dedicated Ethernet port inside the library. Use a tape measure to make an approximation of length needed. 25 ft. and 50 ft. cables were supplied with the kit. If a longer cable is needed, just let us know.



3

Unscrew and disassemble all parts of the UTP Enclosure Connector (Part 10) that are outside of the Enclosure.

**4**

Find the longer Ethernet Cable whose length you determined in step 2 above. For example: 50 feet.



5

Take one end of the Ethernet Cable and feed it through the round end of the plastic cap screw.



6

Put the split rubber washer on the Ethernet Cable between the plastic cap screw and the jack.



7

Push down on the Ethernet jack's locking pin and push it through the narrower end of the last plastic piece. This is a tight fit, and it will feel like you really have to push it through once you get it started.



8

Plug the Ethernet Jack into the receptacle connected to the Enclosure.



9

Re-assemble the UTP Enclosure Connector by screwing each part back together until tight.



10

Plug in the other end of the long Ethernet Cable to the jack on the POE Injector marked with "POE". Plug the short Ethernet Cable (5 ft.) into the "LAN" jack.



11

Talk to the person at your library responsible for the library's network (typically IT) about assigning a static IP address to the Raspberry Pi using the physical port identified in Step 2. Your Pi will likely first be assigned a 'dynamic' address through DHCP, but we want to move to a static IP before installation. If needed, your Pi's MAC address is:

Note: For smaller libraries without this kind of technical support, please see the Networking section in Troubleshooting.

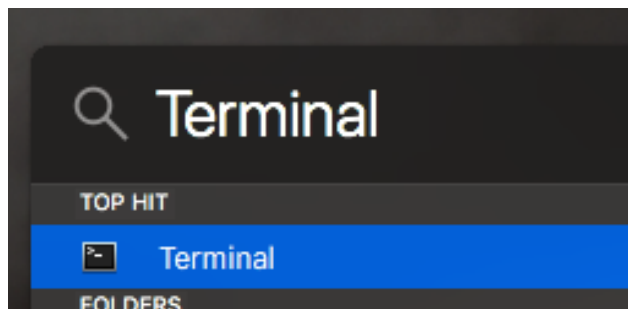
12

The following steps could require input from your IT staff, if your library has them. Bring the Enclosure with connected POE Injector to the place in your library where you will plug everything in for the final installation. Connect the POE Injector to power and plug in the other end of the short Ethernet Cable to the appropriate port on your network.



13

Power on the Macbook (Tool 8). Click the magnifying glass in the upper-right corner, type in Terminal, and press Return.



14

In terminal type this command to log in to your Pi:

```
ssh pi@xxx.xxx.xxx.xxx
```

replacing the xxx.... with the dynamic IP address currently being used by your Pi (work with your IT staff or see Troubleshooting - Networking to find this)

A screenshot of a terminal window on a Mac. The title bar at the top shows a home icon, the name 'cephus', and the command prompt '-bash' followed by the window size '80x24'. The terminal content shows the output of an SSH command: 'Last login: Thu Apr 16 10:50:09 on ttys000' followed by the prompt '(base) Nicos-MacBook-Pro:~ cepheus\$ ssh pi@192.100.0.17'.

```
cephus — -bash — 80x24
Last login: Thu Apr 16 10:50:09 on ttys000
(base) Nicos-MacBook-Pro:~ cepheus$ ssh pi@192.100.0.17
```

15

When the Raspberry Pi prompts for a password, type in:

raspberrypi

and press the Return key.

Note: The command line will not show you typing the password indicated by ********* as is typical with websites. If you get a message about creating a SHA-256 fingerprint, type **yes**, and press Return again.

```

Last login: Fri Apr 17 14:36:50 on ttys000
(base) Nicos-MacBook-Pro:~ cepheus$ ssh pi@192.168.000.017
The authenticity of host '192.168.000.017 (192.168.0.17)' can't be established.
ECDSA key fingerprint is SHA256:6BP3bWx48azn8yUaOcVMJMC0m+b+qdyJ37y+s5T9zEc.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added '192.168.000.017,192.168.0.17' (ECDSA) to the list of known hosts.
pi@192.168.000.017's password:
Linux raspberrypi 4.19.97-v7l+ #1294 SMP Thu Jan 30 13:21:14 GMT 2020 armv7l

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.

SSH is enabled and the default password for the 'pi' user has not been changed.
This is a security risk - please login as the 'pi' user and type 'passwd' to set a new password.

Wi-Fi is currently blocked by rfkill.
Use raspi-config to set the country before use.

pi@raspberrypi:~ $

```

16

Type the command:

sudo nano /etc/dhcpd.conf

and press the Return key to execute it.

the exact distribution terms for each program are
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY
permitted by applicable law.

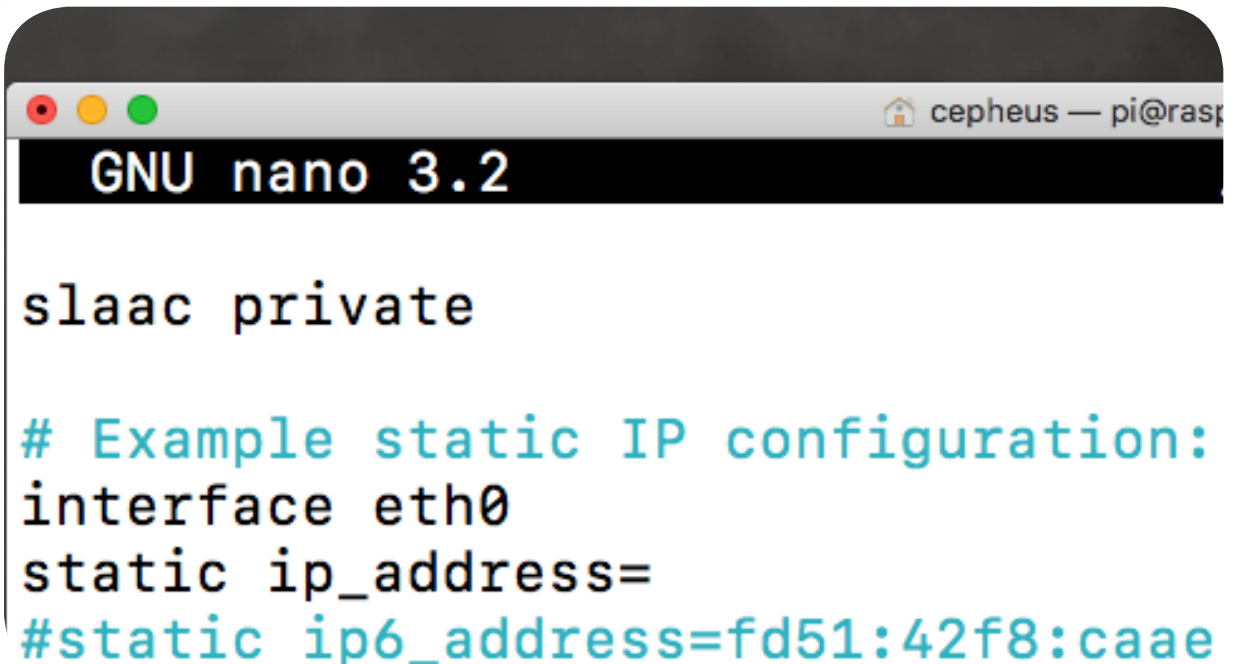
Last login: Thu Apr 16 15:52:29 2020 from 131.142

pi@raspberrypi:~ \$ sudo nano /etc/dhcpd.conf

17

Press the down arrow until you get to a section of this file that starts with:

#Example static IP configuration:



```
GNU nano 3.2

slaac private

# Example static IP configuration:
interface eth0
static ip_address=
#static ip6_address=fd51:42f8:caae
```

Remove the # from the following lines to un-comment them:

```
interface eth0
static ip_address=
static routers=
static domain_name_servers=
```

18

```
# Example static IP configuratio
interface eth0
static ip_address=
#static ip6_address=fd51:42f8:ca
static routers=
static domain_name_servers=
#fd51:42f8:caae:d92e::1
```

19

The first line should be: interface eth0. This tells the Raspberry Pi that we are setting the static IP on the Ethernet port not the Wifi Adapter. Ask your IT staff how to set the other 3 lines. Note: the ip_address should be in slash notation (e.g. xxx.xxx.xxx.xxx/24) To find the correct format, see: https://en.wikipedia.org/wiki/Classless_Inter-Domain_Routing#IPv4_CIDR_blocks

a.b.c.d/27	+0.0.0.31	255.255.255.224	
a.b.c.d/26	+0.0.0.63	255.255.255.192	
a.b.c.d/25	+0.0.0.127	255.255.255.128	
a.b.c.0/24	+0.0.0.255	255.255.255.0	
a.b.c.0/23	+0.0.1.255	255.255.254.0	
a.b.c.0/22	+0.0.3.255	255.255.252.0	
a.b.c.0/21	+0.0.7.255	255.255.248.0	
a.b.c.0/20	+0.0.15.255	255.255.240.0	

20

Double check all values, then press CTRL and O to save and then CTRL and X to exit the file.

```

GNU nano 3.2 /etc/dhcpd.conf

slaac private

# Example static IP configuration:
interface eth0
static ip_address=192.168.0.20/24
#static ip6_address=fd51:42f8:caae:d92e::ff/64
static routers=192.168.0.1
static domain_name_servers=192.168.0.1 8.8.8.8 fd

# It is possible to fall back to a static IP if

```

21

Type the command:

sudo reboot

and press the Return key to execute it.

```
distribution terms for each program.  
files in /usr/share/doc/*/copyright.  
  
Linux comes with ABSOLUTELY NO WARRANTY  
or applicable law.  
Thu Apr 16 15:52:29 2020 from 132.161.251.100  
yp1:~ $ sudo nano /etc/dhcpd.conf  
yp1:~ $ sudo reboot
```

22

Wait 1 minute, then type:

ssh pi@xxx.xxx.xxx.xxx

and press Return. This time using the static IP address you just set up.

```
cepheus — -bash — 80x24  
Last login: Thu Apr 16 10:50:09 on ttys000  
(base) Nicos-MacBook-Pro:~ cepheus$ ssh pi@192.100.0.31
```


23

To configure the settings of the Raspberry Pi, type in the command:
sudo raspi-config
 and press the Return key to execute.

```
ms included with the Debian GNU/L
distribution terms for each progr
files in /usr/share/doc/*/copyri

/Linux comes with ABSOLUTELY NO W
by applicable law.
: Thu Apr 16 15:53:14 2020 from 1
rypi:~ $ sudo raspi-config
```

24

Press the Return key to select the first option: **Change User Password**.
 Change the default password from **raspberry** to something more secure
 by following the instructions to change your password. Take precautions to
 remember this password. Note: the command line will not show you typing
 indicated by ********* as is typical with websites.

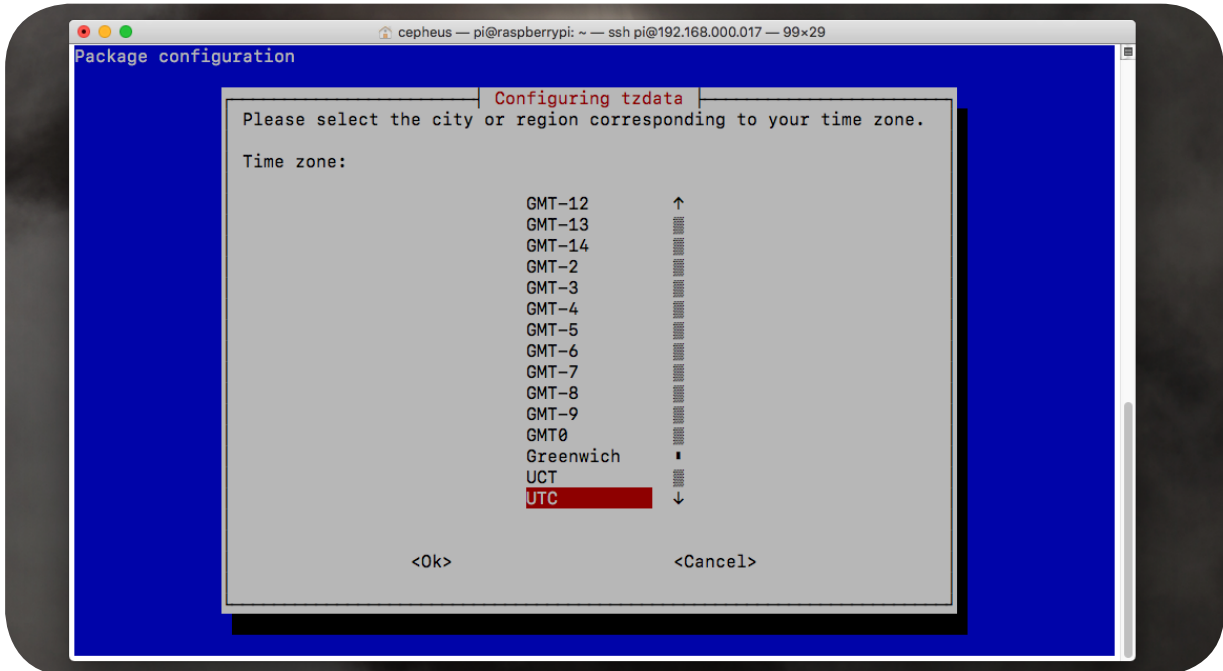
Raspberry Pi 4 Model B Rev 1.1

Raspberry Pi Software Configuration Tool (raspi-confi

1	Change User Password	Change password for the 'pi' user
2	Network Options	Configure network settings
3	Boot Options	Configure options for start-up
4	Localisation Options	Set up language and regional settings t
5	Interfacing Options	Configure connections to peripherals
6	Overclock	Configure overclocking for your Pi
7	Advanced Options	Configure advanced settings
8	Update	Update this tool to the latest version
9	About raspi-config	Information about this configuration to

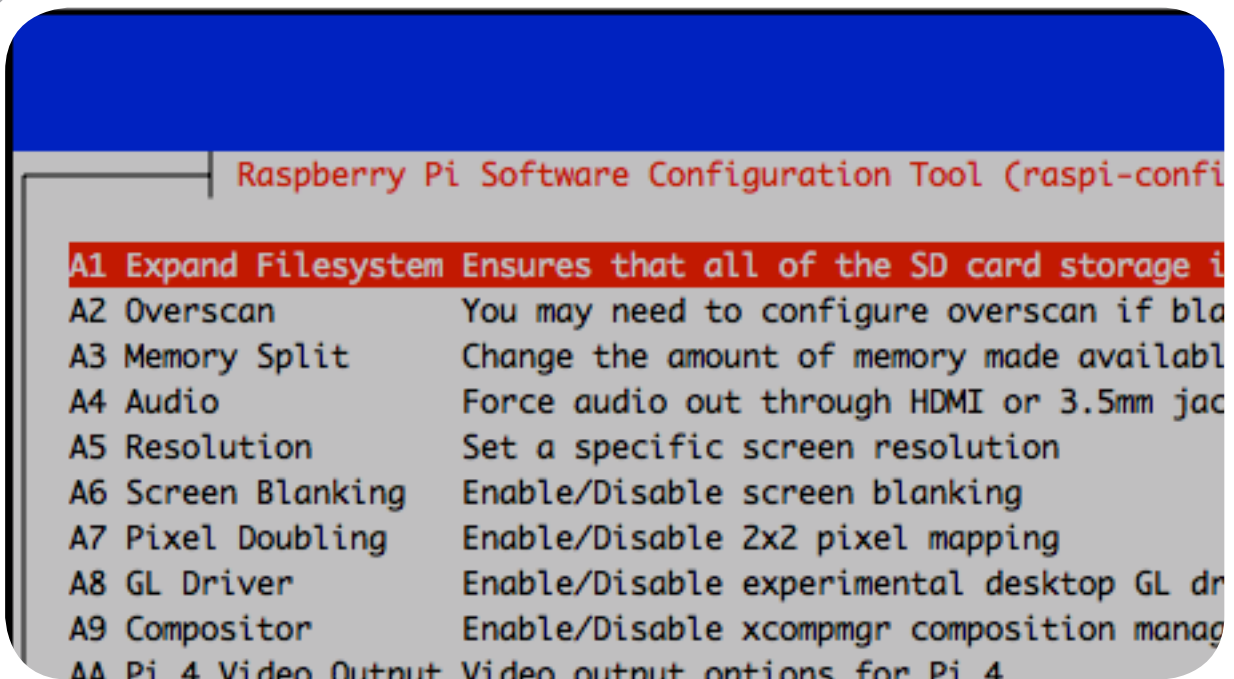
25

Press the Down arrow key until **4 Localisation Options** is selected and press the Return key to select it. From Localisation options you can change the default language, timezone, and keyboard layout. For the timezone, choose **None of the above** and then pick **UTC** to set your station to Coordinated Universal Time, which is used by SatNOGS.



26

Press the Right arrow key and then the Return key to go **<Back>**. Press the Down arrow key a few times followed by the Return Key to choose Advanced Options. Select the first option to **Expand the File System**. When done return to the main menu by pressing the Right Arrow key and then the Return key to go **<Back>**.



27

Press the Right arrow key, to select **<Finish>**, and press Return.
Type the command:
sudo reboot
and press Return again.

```
NU/Linux comes with ABSOLUTELY NO
d by applicable law.
in: Thu Apr 16 15:52:29 2020 from
errypi:~ $ sudo nano /etc/dhcpd.
errypi:~ $ sudo reboot
```

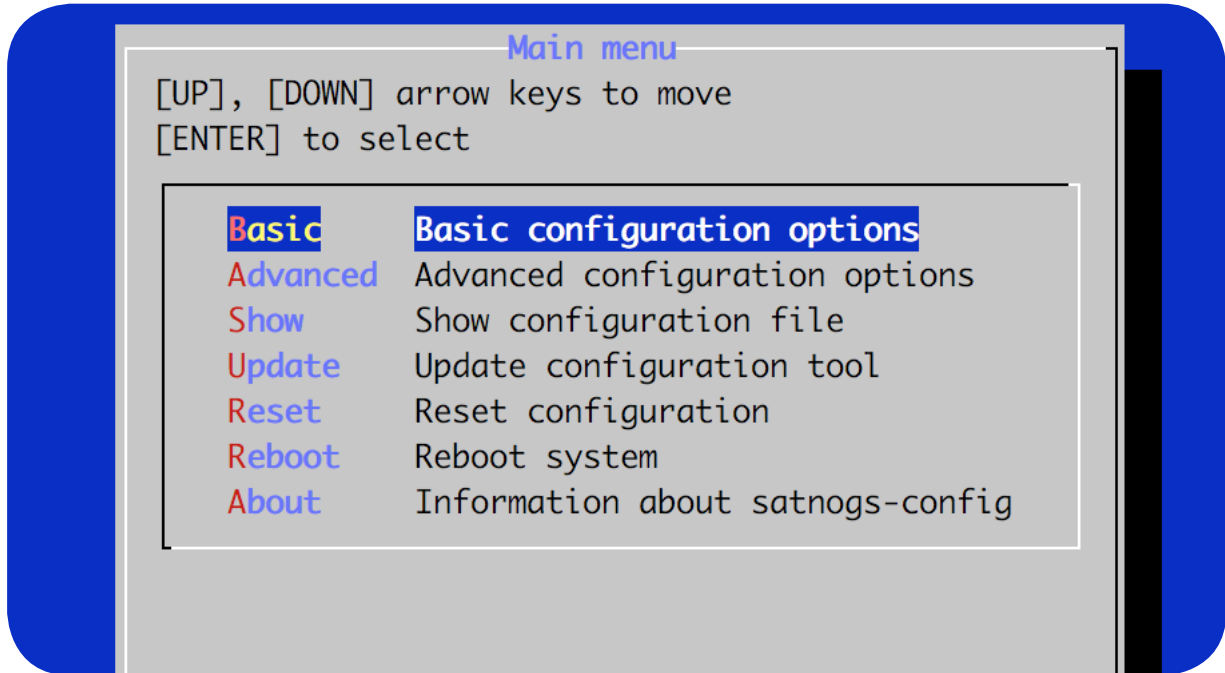
28

Wait 1 minute, then type: **ssh pi@xxx.xxx.xxx.xxx** replacing the Xs with the **static IP address** you set up for the Pi. Enter your new strong password when prompted.

```
cepheus — -bash — 80x24
Last login: Thu Apr 16 10:50:09 on ttys000
(base) Nicos-MacBook-Pro:~ cepheus$ ssh pi@192.100.0.31
```


29

Type the command **sudo satnogs-setup** followed by the Return key. A gray box with options on a blue background should appear. We will configure this after the ground station is installed. All we have to check now is that this command brings up the configuration client. Press the Right arrow key twice to select Exit and press Return.

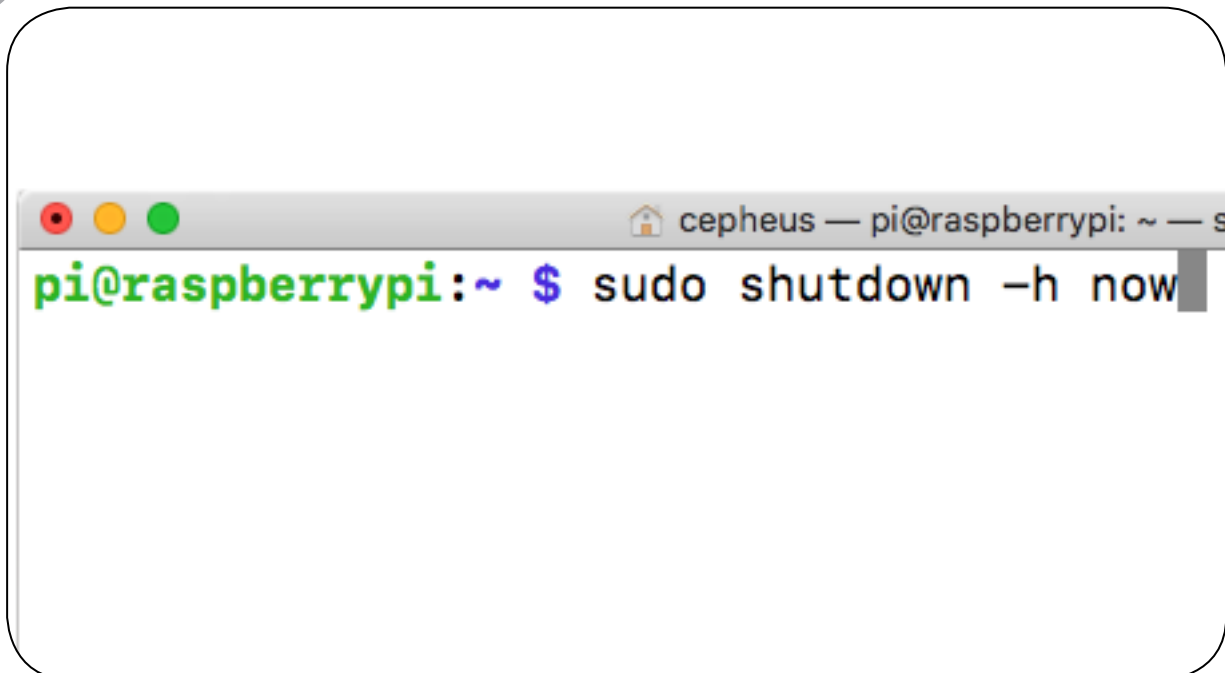


30

Type the command:

sudo shutdown -h now

followed by the Return key. Wait a few seconds, and then disconnect the long Ethernet Cable from the POE injector. You are now ready to install the ground station on your roof!



F. CONFIGURING THE STATION (POST INSTALLATION)

Introduction

Now that your ground station is installed on the roof, we need to do a few last configuration steps with the SatNOGS website and client before we can schedule the station's first observation of a satellite. These steps will be done with the MacBook (Tool 8) using a web browser, and the Terminal (command-line).

Tools Needed in this Section

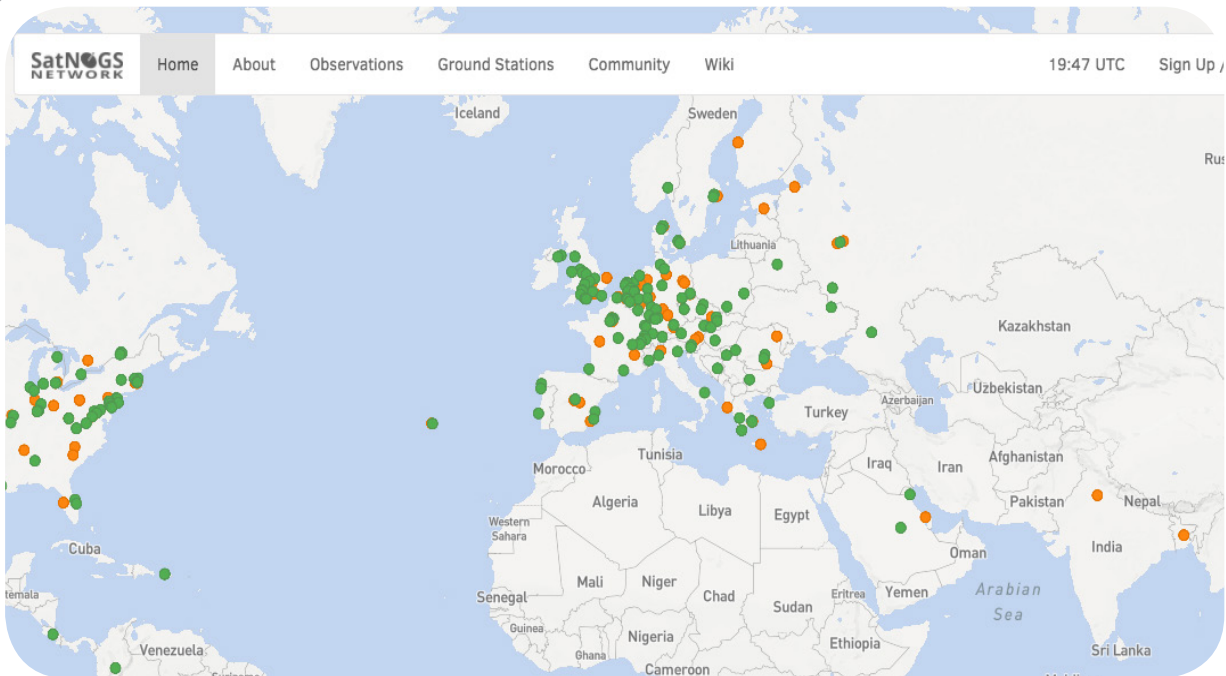


Tools

8. MacBook

1

Go to the main page for the SatNOGS network of ground station at:
<https://network.satnogs.org/>



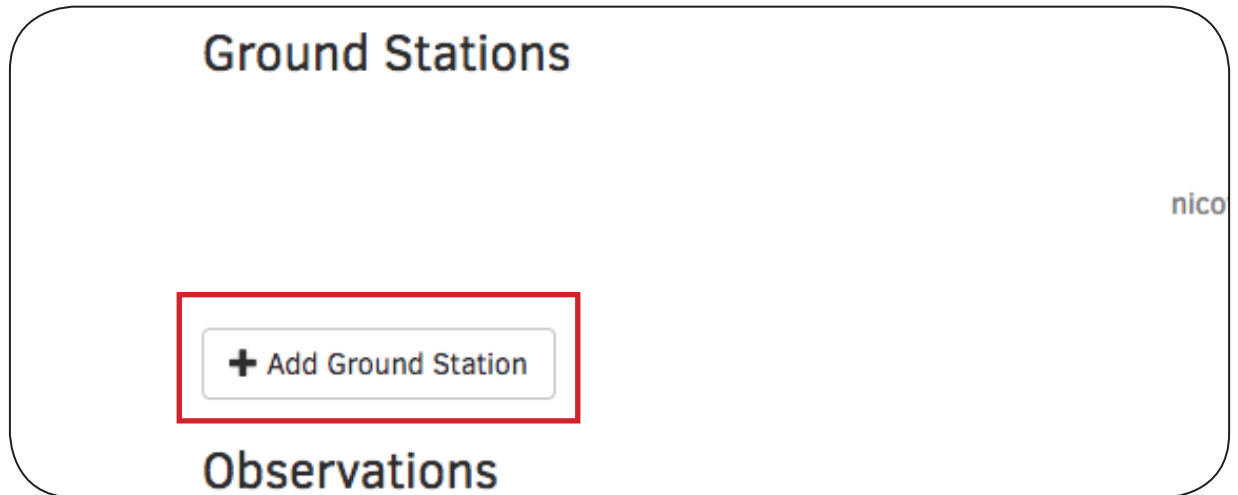
2

Click the Sign Up/Log in link in the upper-right, choose sign-up and fill in the three fields.

A screenshot of the SatNOGS Network Sign Up form. The header shows 'SatNOGS Network' and two tabs: 'Log In' and 'Sign Up'. The 'Sign Up' tab is selected. Below the tabs are three input fields: an email field with the placeholder 'yours@example.com', a username field with the placeholder 'your username', and a password field with the placeholder 'your password'. Each field has an icon on the left: an envelope for email, a person for username, and a lock for password. At the bottom of the form is a large blue button labeled 'SIGN UP >'. The entire form is set against a dark background.

3

You will be brought to your Dashboard. Click the “+ Add Ground Station” button.



4

Fill out the information in the form. To find your Latitude/Longitude and Altitude (in meters), you can use <https://www.latlong.net/> and <https://www.whatismyelevation.com/>. Please add an image of your installed ground station. For Min. Horizon, please estimate based on your location (If on a roof with no major obstructions, 15 degrees is a good guess). For Target Utilization, please choose 100%. For Antenna, please choose Eggbeater for the type, and 430.000 MHz-440.000 MHz (UHF) for the frequency range. Click Submit.

Add Ground Station

General Info

Name: Wolbach Library

Description: public libraries. More information at: <https://lstn.wolba.ch>. Kit: Raspberry Pi 4 Model B; Uputronics LNA; LimeSDR Mini; M2 EB-432/RK70cm; MiniCircuits RF Cables, RF Elements StationBox

Location

Latitude: 42.382 Longitude: -71.128 Altitude (ASL): 15

QTH Locator: FN42kj

Image

Settings

Minimum Horizon: [Slider]

Target Utilization: [Slider]

☒ Testing?

Antennas

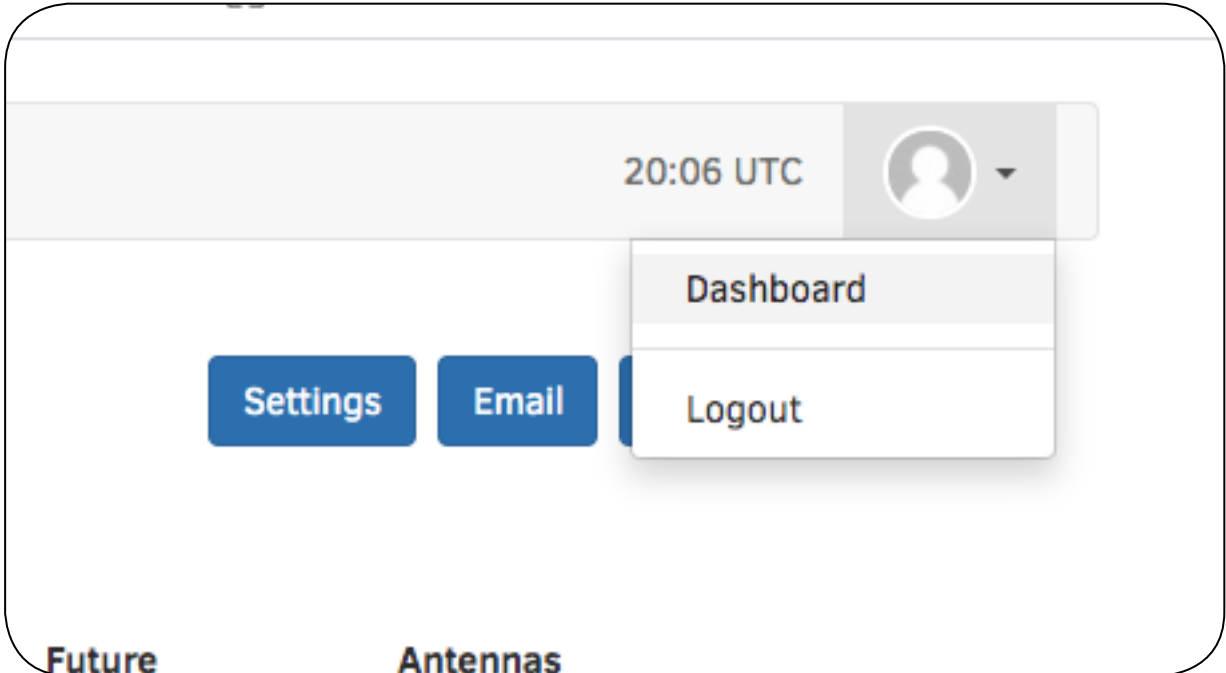
Type: Eggbeater

Frequency Ranges: 430.000 MHz - 440.000 MHz (UHF)

[Back to Dashboard](#) [Submit](#)

5

Click on your user icon in the upper-right and return to your Dashboard. Keep this page open as we will need to copy-paste your API Key from this page in a later step.



6

Click the magnifying glass in the upper-right of your Mac and type in Terminal. With Terminal open, type in the command: `ssh pi@xxx.xxx.xxx.xxx` substituting the xxx.. with your static IP address for the Pi. Log in to your Pi with the password you set up previously.

```

Last login: Thu Apr 16 10:50:09 on ttys000
(base) Nicos-MacBook-Pro:~ cepheus$ ssh pi@lstn.cfa.harvard.edu
pi@lstn.cfa.harvard.edu's password:
Linux raspberrypi 4.19.97-v7l+ #1294 SMP Thu Jan 30 13:21:14 GMT 2020 armv7l

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
Last login: Thu Apr 16 15:52:29 2020 from 131.142.33.100
pi@raspberrypi:~ $

```

7

Type in the command:

sudo satnogs-setup

and enter Basic configuration by pressing Return

```

SatNOGS client configuration | Installed: satnogs-client-ansible-202003221112
Basic configuration options
[UP], [DOWN] arrow keys to move
[ENTER] to select

SATNOGS_API_TOKEN      *Define API token
SATNOGS_SOAPY_RX_DEVIC *Define Soapy RX device
SATNOGS_ANTENNA        *Define SatNOGS Radio Antenna
SATNOGS_RX_SAMP_RATE   *Define RX sampling rate
SATNOGS_STATION_ELEV   *Define station elevation
SATNOGS_STATION_ID     *Define station ID
SATNOGS_STATION_LAT    *Define station latitude
SATNOGS_STATION_LON    *Define station longitude

<select>          < Back >
  
```

Go back to the web browser. From your SatNOGS Network Dashboard, click on the blue API Key Button. From the window that pops up, select and copy (Command-C) the long string of numbers and letters. Note: Never share your API Key with anyone, as that will compromise the security of your ground station. If you accidentally share your API Key, please let us know, and we can create a new one.

8

API Key

You can use this token to interact with the API.

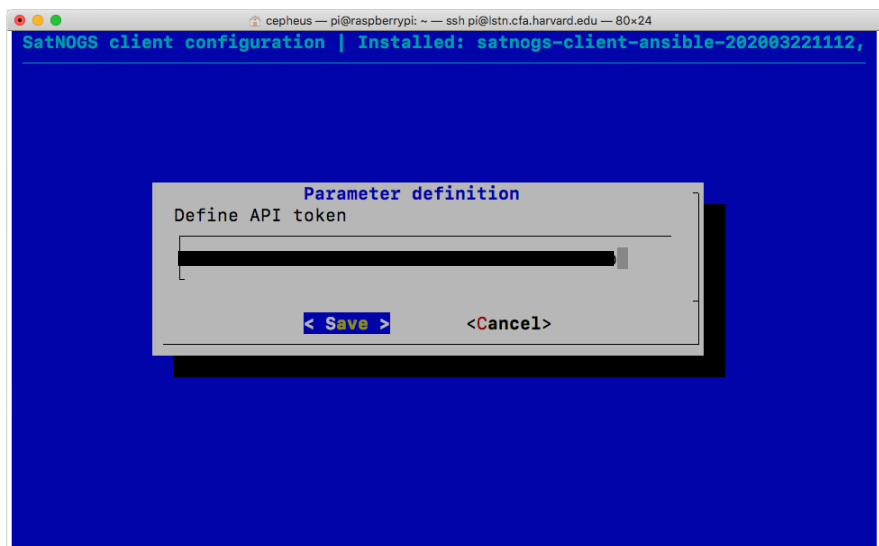
9312...378

Location

Total

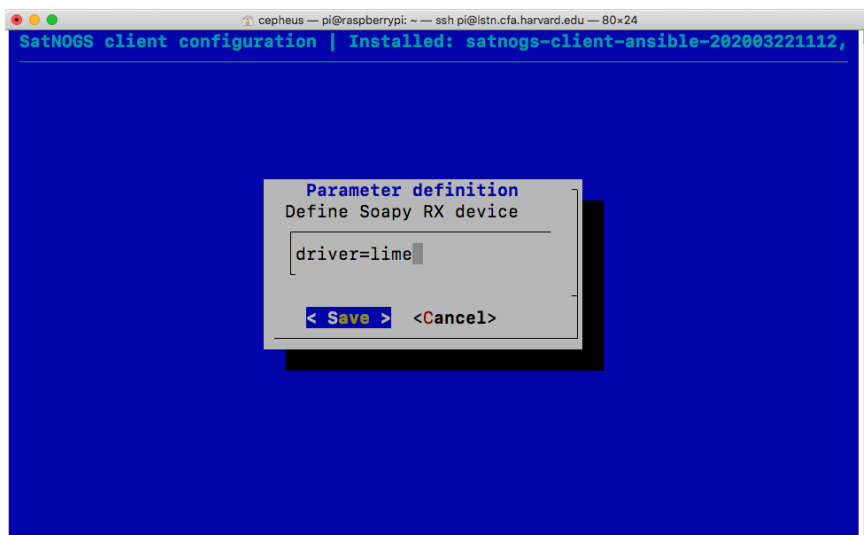
9

Switch back to Terminal. Press Return to enter the API Key setting, then press Command-V to paste your API Key into the field. Press Return to save.



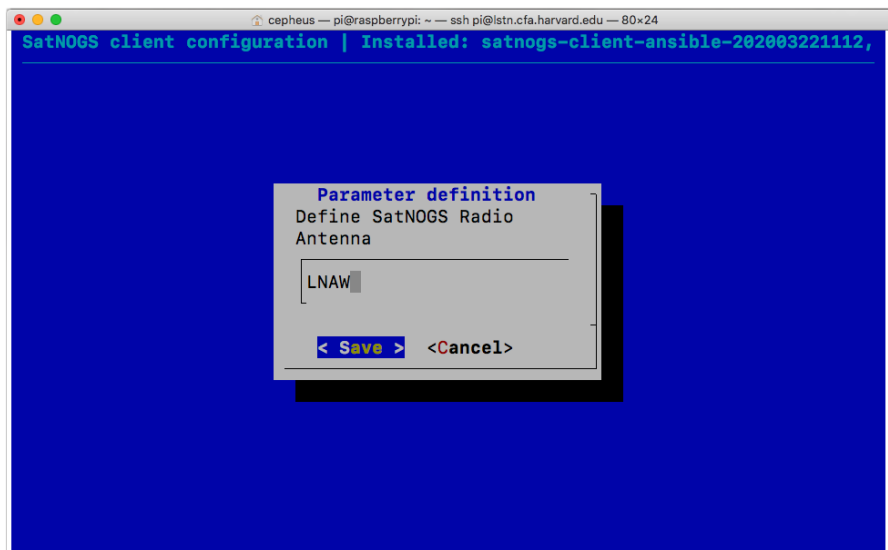
10

Press the Down arrow key on your keyboard then Return to enter the SATNOGS_SOAPY_RX_DEVICE field. Type in: **driver=lime** and press Return to save.



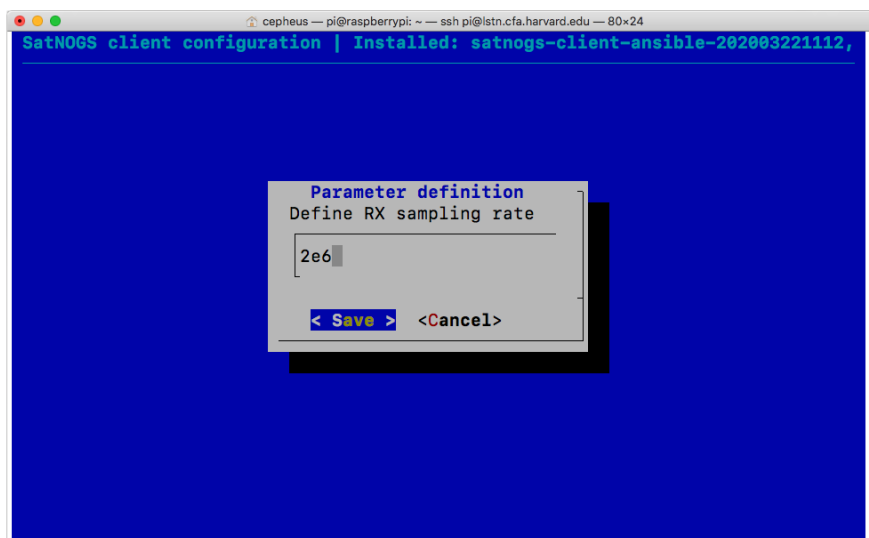
11

Press the Down arrow then Return to enter the SATNOGS_ANTENNA field.
Type in:
LNAW
and press Return to save.



12

Press the Down arrow then Return to enter the SATNOGS_RX_SAMP_RATE field. Type in:
2e6
and press Return to save.



13

Go back to the web browser and click on your ground station from your dashboard. For the next four fields, just copy this information from your ground station page.

1468	Wolbach Lib test
Owner	nicotest
QTH Locator	FN42ki
Coordinates	42.365°, -71.105°
Altitude	15 m

14

The Basic Configuration options should now be complete (all filled in). Press the Right arrow key on your keyboard to choose "Back" then press Return.

```

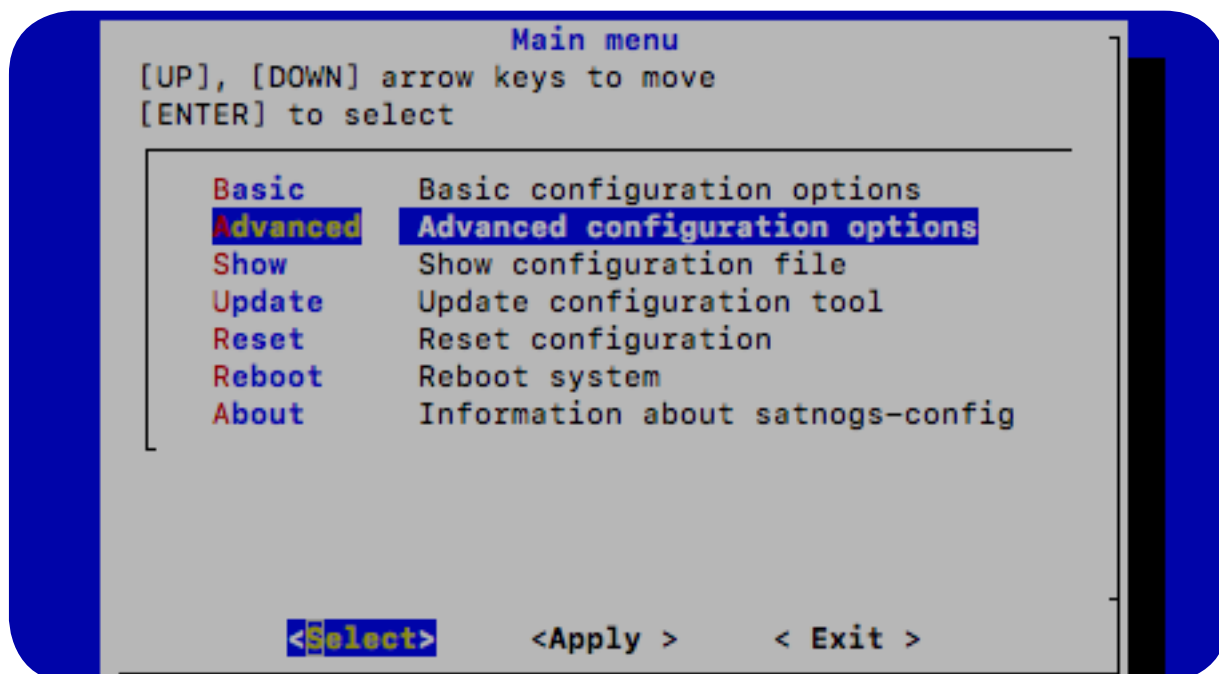
Basic configuration options
[UP], [DOWN] arrow keys to move
[ENTER] to select

SATNOGS_API_TOKEN          *Define API token
SATNOGS_SOAPY_RX_DEVICE    *Define Soapy RX device [driver=lime]
SATNOGS_ANTENNA            *Define SatNOGS Radio Antenna [LNAW]
SATNOGS_RX_SAMP_RATE       *Define RX sampling rate [2.048e6]
SATNOGS_STATION_ELEV       *Define station elevation [15]
SATNOGS_STATION_ID         *Define station ID [1378]
SATNOGS_STATION_LAT        *Define station latitude [42.382]
SATNOGS_STATION_LON        *Define station longitude [-71.128]

<Select>                < Back >
  
```

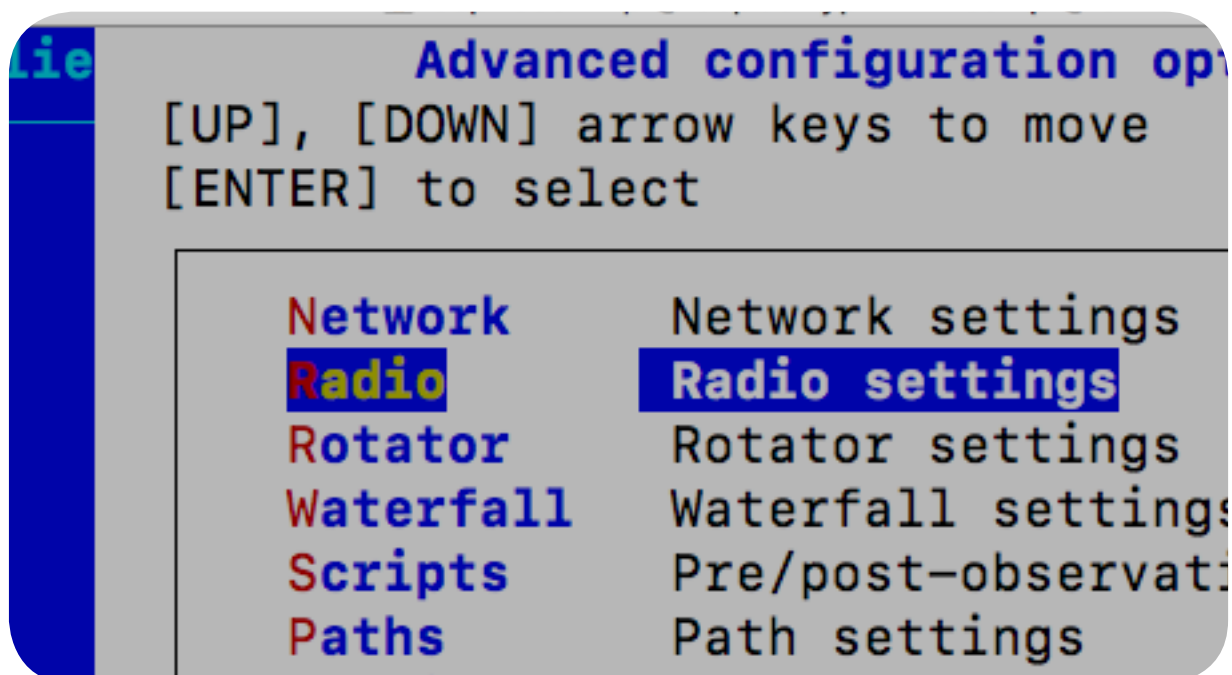

15

Press the Down arrow key on your keyboard to choose “Advanced configuration options” then press Return to select it.



16

Press the Down arrow key and then Return to select “Radio”

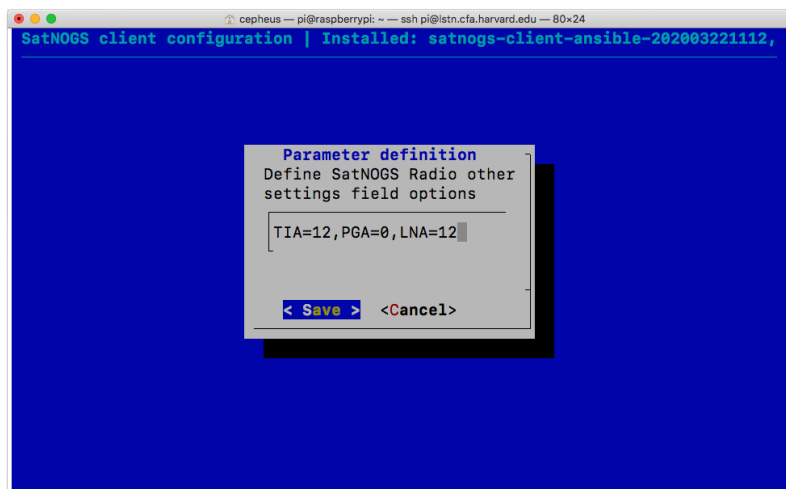


17

Using your Down arrow key and Return key to navigate to different settings in the Radio options, enter in the following values for these settings:

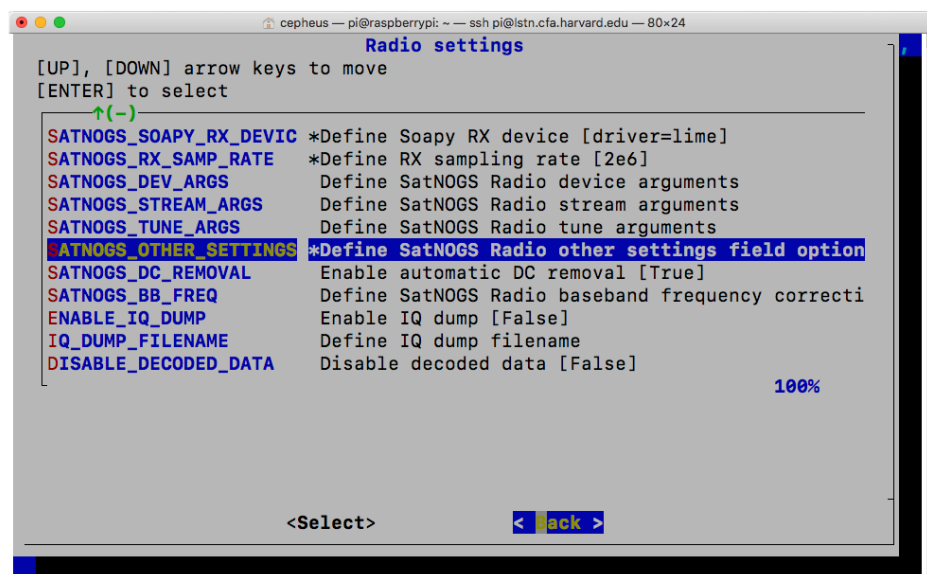
SATNOGS_GAIN_MODE: **Settings Field**

SATNOGS_OTHER_SETTINGS: **TIA=12,PGA=0,LNA=12**



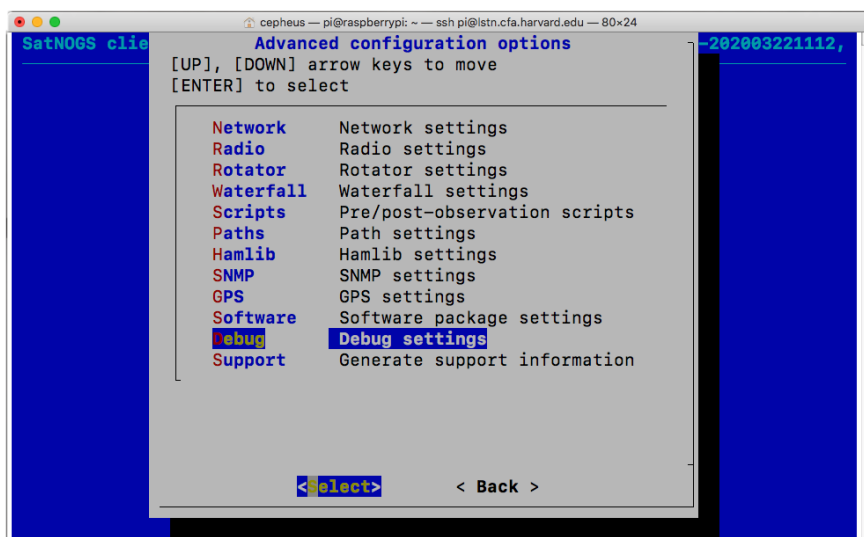
18

Step 17 is how we set the gain for the Software Defined Radio (Part 5). After these are entered, press the Right arrow key to choose “Back” and then press the Return key.



19

Press the Down arrow key multiple times until you have Debug selected and press the Return key.

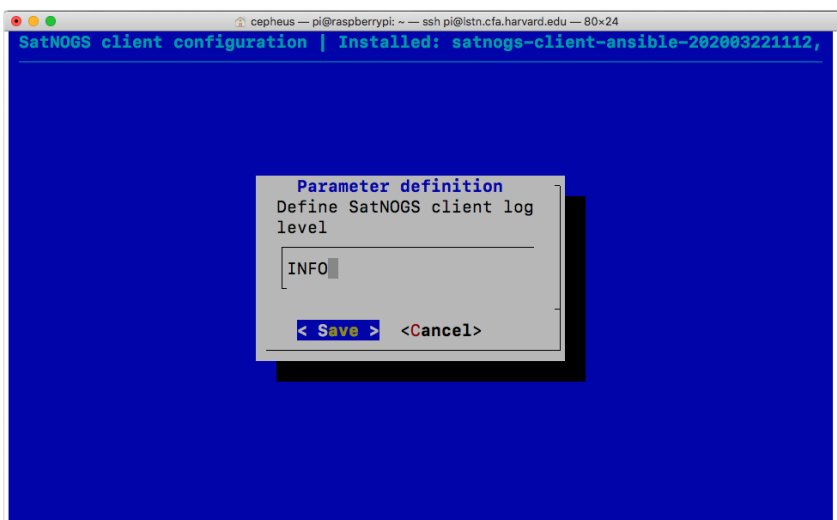


20

Select the first option "Define SatNOGS client log level" and press Return, then type in:

INFO

and press Return again to save. Press the Right arrow key to choose "Back" and then press the Return key.



21

Press the Right arrow key and choose “Back” again to return to the main menu.

```

Main menu
[UP], [DOWN] arrow keys to move
[ENTER] to select

Basic      Basic configuration options
Advanced   Advanced configuration options
Show       Show configuration file
Update     Update configuration tool
Reset      Reset configuration
Reboot     Reboot system
About      Information about satnogs-config

<Select>  <Apply >  < Exit >

```

22

Press the Down arrow key to choose “Show” and press Return. Double check that you have all of these settings in your configuration file. Press Return to go Back.

```

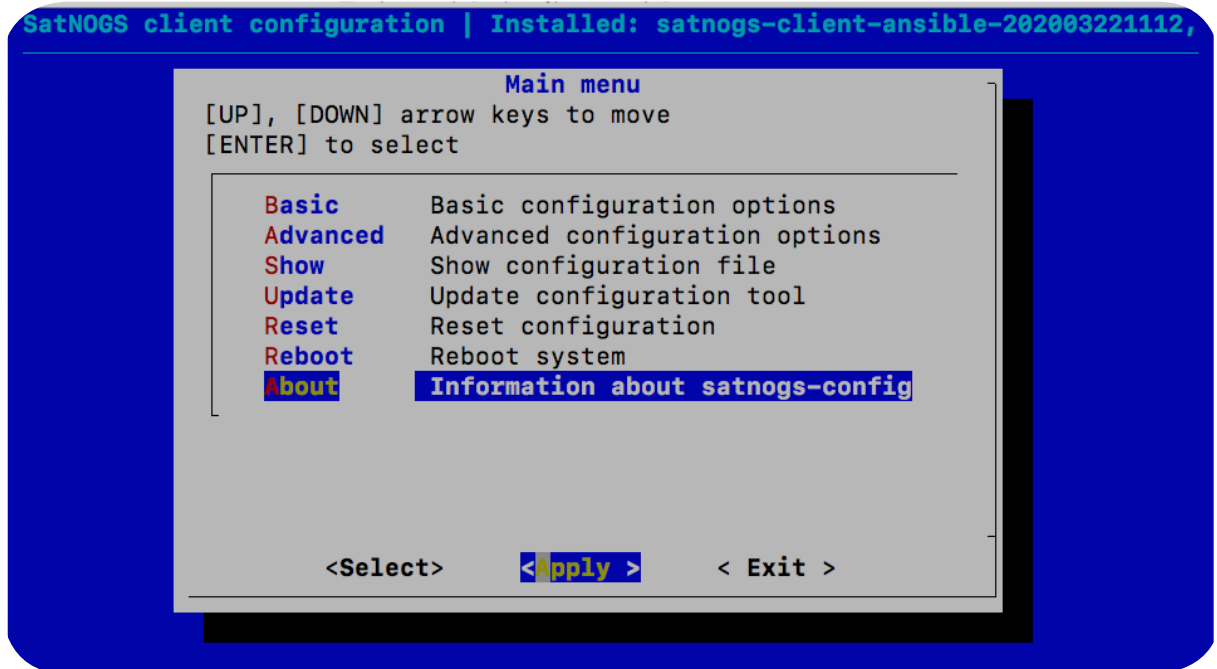
SatNOGS client configuration | Installed: satnogs-client-ansible-202003221112,
SatNOGS client configuration
satnogs_antenna: LNAW
satnogs_api_token: 
satnogs_gain_mode: Settings Field
satnogs_log_level: INFO
satnogs_other_settings: TIA=12,PGA=0,LNA=12
satnogs_rx_device: limesdr
satnogs_rx_samp_rate: 2e6
satnogs_soapy_rx_device: driver=lime
satnogs_station_elev: '15'
satnogs_station_id: '1378'
satnogs_station_lat: '42.382'
satnogs_station_lon: '-71.128'

< Back >

```

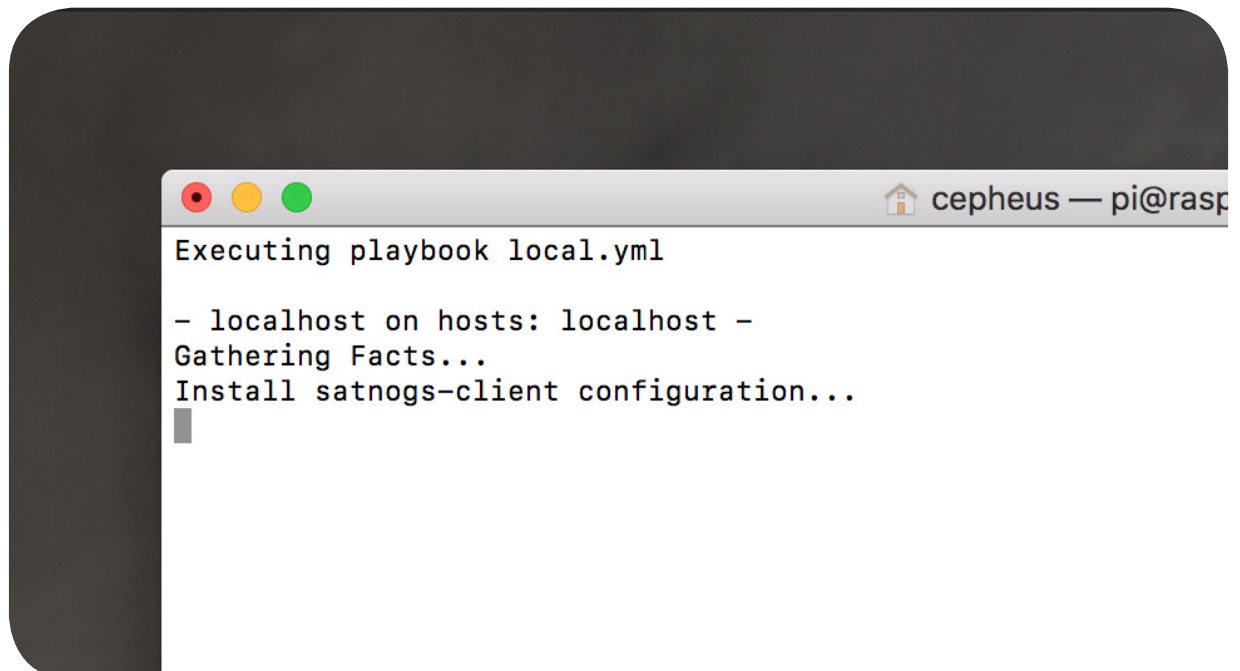
23

Press the Right arrow key to choose “Apply”, and press Return. Note: Make sure to do this step. It is easy to forget to apply the changes. They are not actually saved until you apply them.



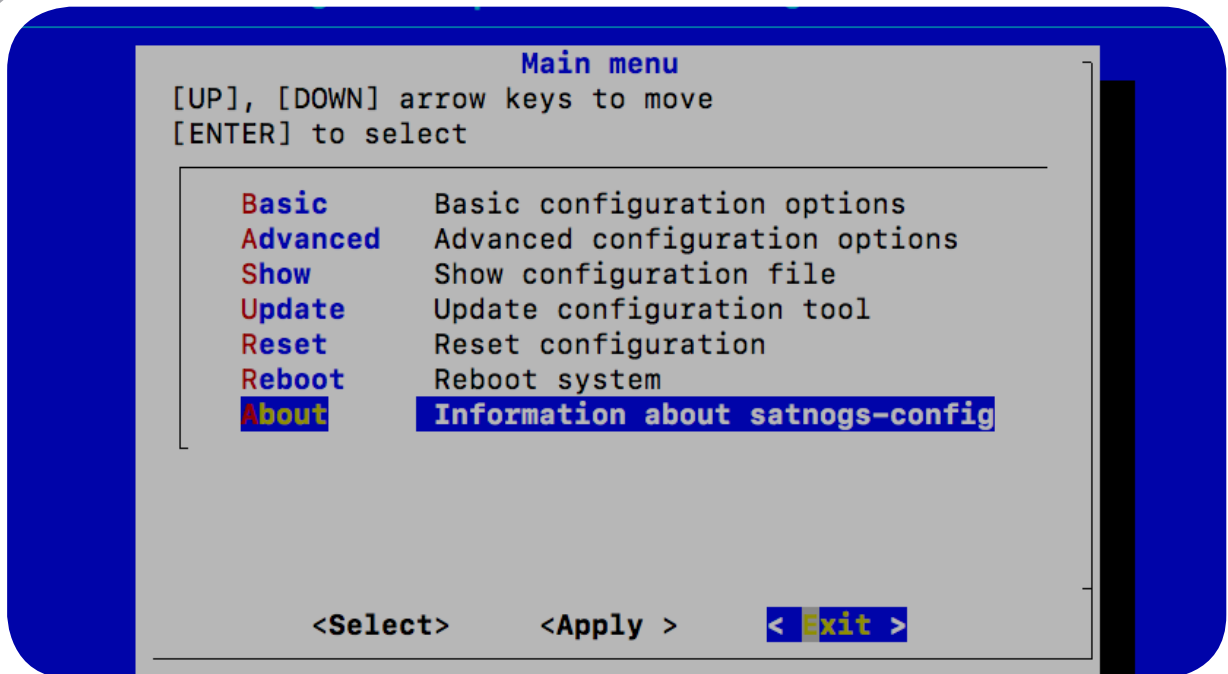
24

Wait a few moments for the system to apply the settings.



25

Press the Right arrow key again to choose “Exit”, and press Return.

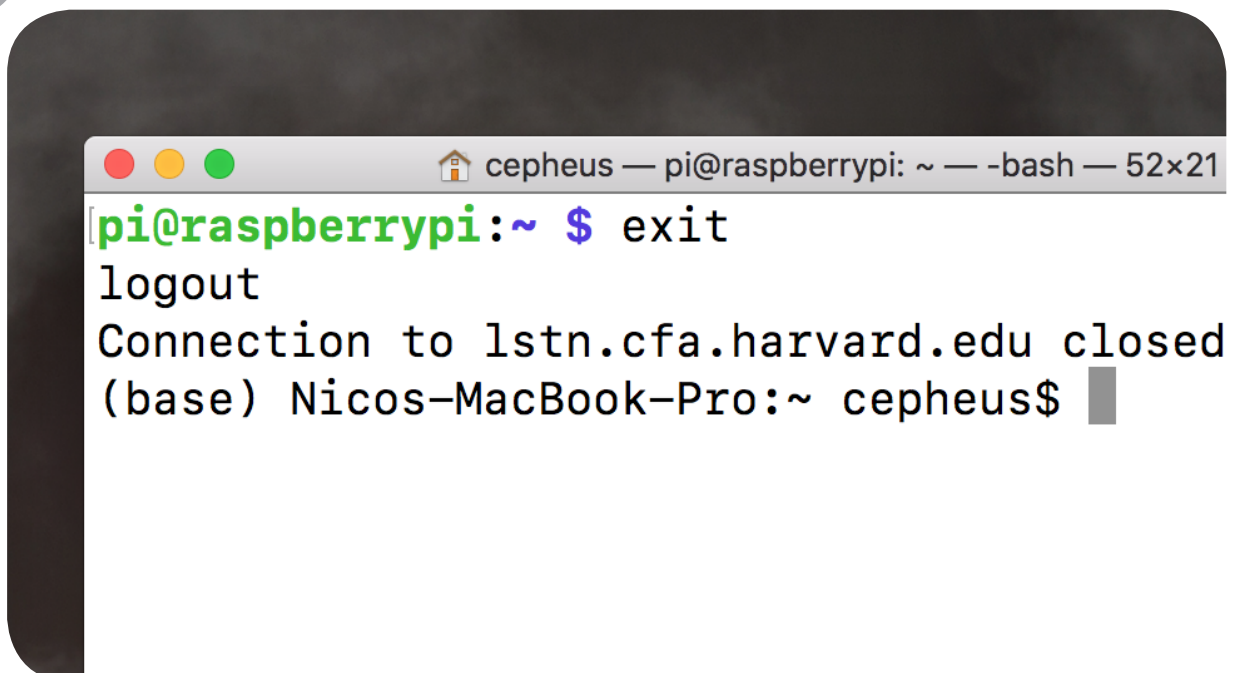


26

Type the command:

exit

and press Return to log out from your Pi session.



27


Go back to the web browser, and refresh your ground station's page. If everything is working correctly, your ground station should now be talking to the network. Instead of saying "offline" in red it will show "testing" in orange.

An orange rectangular button with the word "Testing" in white text.

Last seen 0 minutes ago

28

On your ground station's page, click the blue "Calculate Future Passes" button.

A blue rectangular button with the text "Calculate Future Passes" in white. The button is enclosed in a red rectangular border.

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☁ Observation data are freely distributed under the [CC BY-SA](#)

29

Find the next upcoming pass for a satellite with a high success rate (bar is mostly green). A high success rate indicates you are more likely to receive a transmission from that satellite. Click the “Schedule” button on the right.

35933-BEESAT	21:56 2020-04-06	22:00 2020-04-06	↑59° ↻26° ↓132°		schedule
44329-Raavana-1	21:59 2020-04-06	22:02 2020-04-06	↑328° ↻37° ↓84°		schedule
44045-MySat-1	22:03 2020-04-06	22:07 2020-04-06	↑299° ↻28° ↓22°		schedule

30

On the New Observation page, click the green “Schedule” button.

Observation

in UTC

44329 - Raavana-1

UHF CW TLM - 437.375 MHz - CW

1378 Wolbach Library

Start Time: 2020-04-06 21:59

End Time: 2020-04-06 22:03

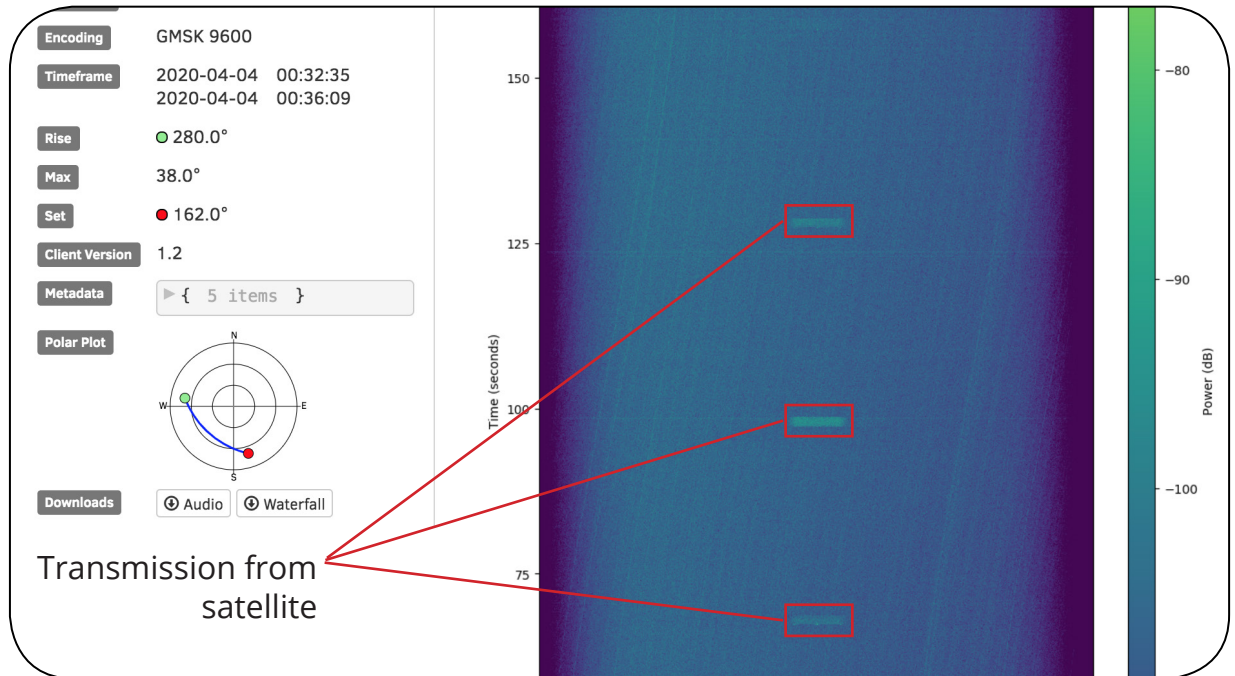
[Calculate](#)

Timeline

Timeline visualization showing a blue bar representing the observation period from 21:59 to 22:03. A red box highlights the [Schedule](#) button.

31

Wait for the observation time to pass. If successful, you will see a “waterfall” with a radio transmission from the satellite in the middle (see example below). If not successful, try scheduling a few more observations. If you are consistently getting blank waterfalls, refer to the SatNOGS Client section in Troubleshooting.

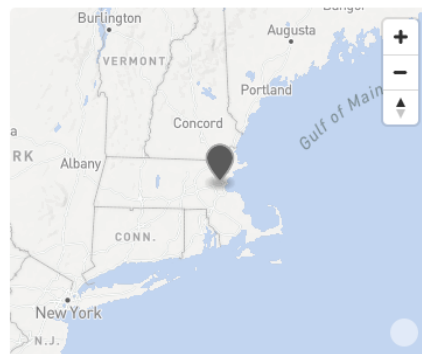


32

Congratulations! Your station is now operational. Feel free to start scheduling more observations of satellites. You can rate the observations after they occur as good, bad, or failed. If the SatNOGS client can decode the data, the observation will be rated as good automatically. See here for more on rating observations: https://wiki.satnogs.org/Operation#Rating_observations. After a few days of good observations, feel free to take your station out of “Testing” mode by setting it to “Online.”

1378 - Wolbach Library

Owner	Nico Carver
QTH Locator	FN42kj
Coordinates	42.382°, -71.128°
Altitude	15 m
Min Horizon	20°
Target Utilization	100 %
Antennas	UHF Eggbeater
Success Rate	<div><div></div></div>
Observations	1417 View all
Creation Date	1 month, 3 weeks ago
Client version	1.2
Online	Last seen 0 minutes ago
Uptime	32 days, 6:21:56 Log



This is one of five stations participating in the pilot phase of LSTN (Library Space Technology Network), a program to support space exploration in public libraries. See the project page at: <https://lstn.wolba.ch>. Kit: Raspberry Pi 4 Model B; Uputronics LNA; LimeSDR Mini; M2 EB-432/RK70cm; MiniCircuits RF Cables, RF Elements Station Board.

TROUBLESHOOTING

In this section, you will find a few tips for troubleshooting your LSTN ground station. As we get more feedback, this section will be expanded. Please always feel free to contact Nico Carver, ncarver@cfa.harvard.edu with questions.

- A. Networking
- B. SatNOGS Client

A. NETWORKING

Issue:

Finding the Raspberry Pi's dynamic IP address on the network for initial setup.

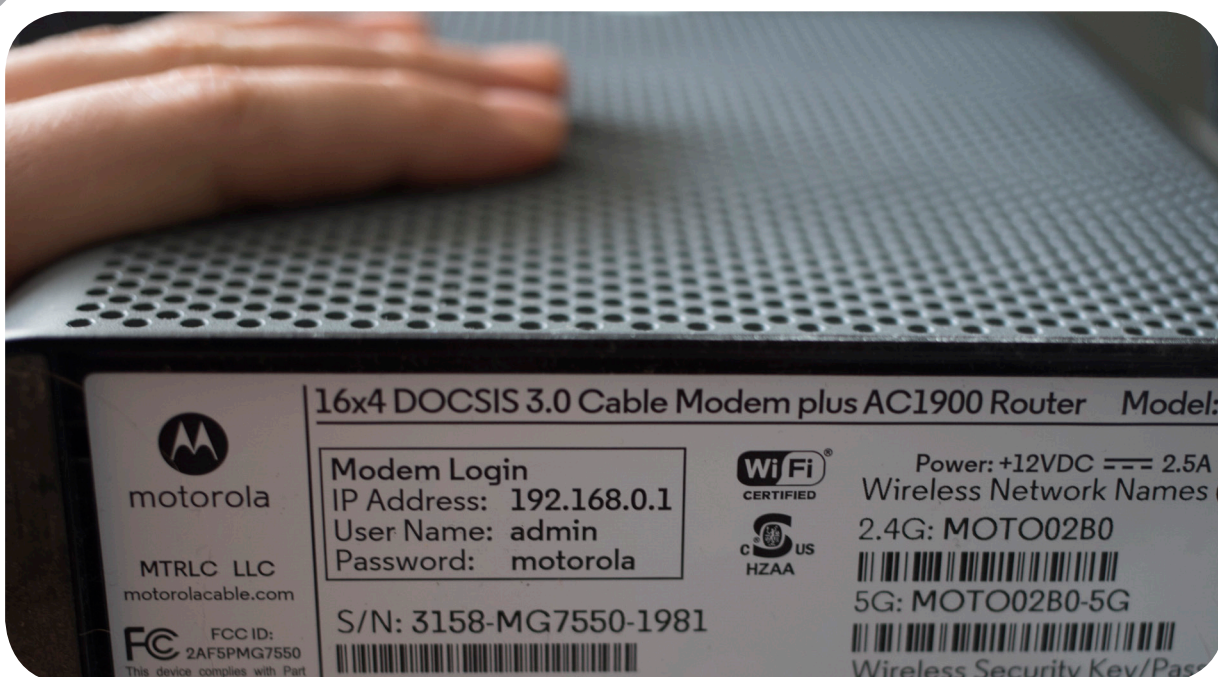
Solution:

If working with your library's IT staff, they should be able to look up the dynamic IP address on the network using your Raspberry Pi's MAC address which is provided on page 52. One way to do this is to ping the broadcast address of the network (for example: `ping 192.168.0.255`) and then after it times out, enter the command: `arp -a` and just find the IP address that matches the physical address (MAC address) of your Pi.

If you are in a smaller library that uses a simple internet router, please see the steps below for an easy way for finding the Pi with your router's admin web interface.

1

Plug your Raspberry Pi into the router. Look on the bottom of your router for login information, and use this to login to your router. If you don't see it, google the name of your router + "login" to find instructions. On my home router, I navigate to 192.168.0.1 and use "admin" for the username and "motorola" for the password.



2

Once logged in, look for the “DHCP” section. For my router, I had to click “Advanced” and then “Basic Router” to get there. In this section, you should hopefully see a list of devices connected to your router and their assigned dynamic IP address. Use the IP address assigned here to the Raspberry Pi to login and follow the rest of the steps in the Prepare for Installation section starting with step 14.

Starting Address of Local Pool 192.168.0.

Number of Addresses in Local Pool

Lease Time of Addresses in Pool (seconds)

DHCP Client List

MAC Address	IP Address	Subnet Mask	Duration	Expires	Hostname
9810e81c7057	192.168.0.0.010	255.255.255.000	D:01 H:00 M:00 S:00	Sat Apr 18 08:33:23 2020	NicholassiPhone
5ceald558588	192.168.0.0.011	255.255.255.000	D:01 H:00 M:00 S:00	Sat Apr 18 07:13:09 2020	BRW5CEA1D5
bce143b76966	192.168.0.0.012	255.255.255.000	D:01 H:00 M:00 S:00	Sat Apr 18 07:41:20 2020	Maggies-iPhone
c8e0eb165ad5	192.168.0.0.014	255.255.255.000	D:01 H:00 M:00 S:00	Sat Apr 18 08:41:41 2020	Nicos-MBP
08058126f1c9	192.168.0.0.016	255.255.255.000	D:01 H:00 M:00 S:00	Sat Apr 18 06:53:59 2020	Roku 4 - 685
dca6321d32f3	192.168.0.0.017	255.255.255.000	D:01 H:00 M:00 S:00	Sat Apr 18 14:05:00 2020	raspberrypi
24f094f38fe8	192.168.0.0.018	255.255.255.000	D:01 H:00 M:00 S:00	Sat Apr 18 12:51:38 2020	Mac-mini

B. SATNOGS CLIENT

Issue:

Any kind of error with SatNOGS including blank waterfalls, observations with no uploads, etc.

Solution:

Login to your Pi using Terminal, and run the command:

`journalctl -f -u satnogs-client.service`

to show your station's logs in real time. You should see something like this as the client checks for new scheduled observations.

1

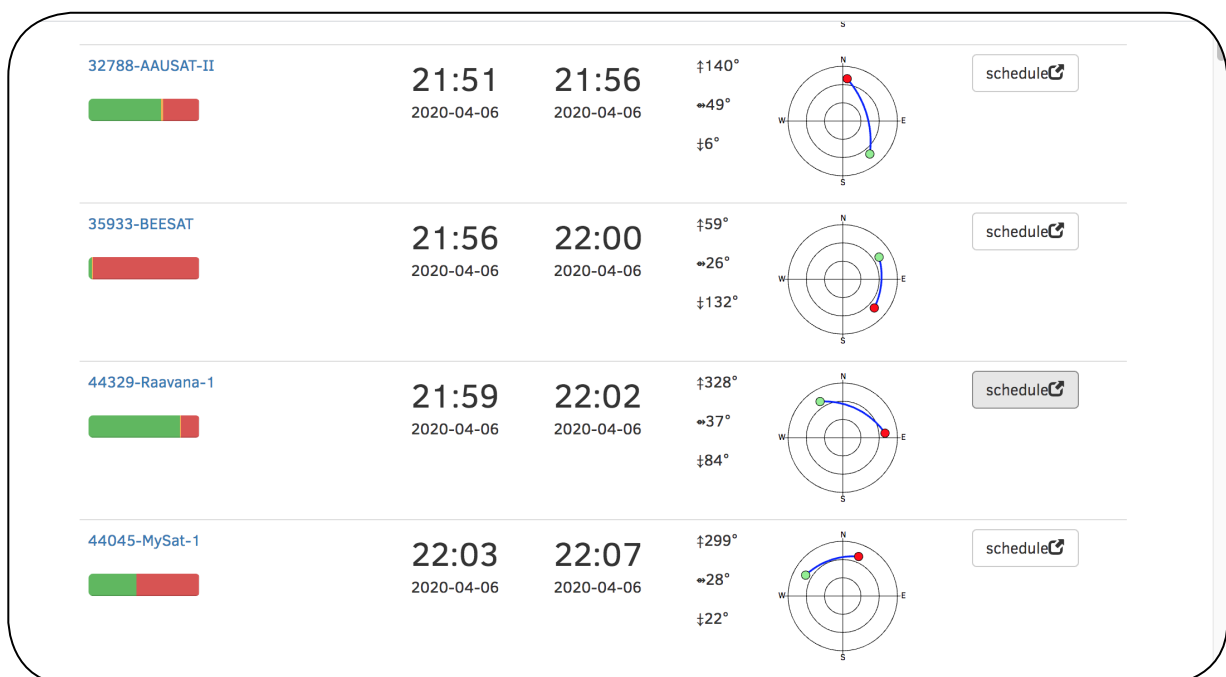
```

cepheus — pi@raspberrypi: ~ — ssh pi@lstn.cfa.harvard.edu — &
Last login: Thu Apr 16 19:50:40 2020 from 131.142.33.100
pi@raspberrypi:~ $ journalctl -f -u satnogs-client.service
-- Logs begin at Thu 2020-03-26 16:40:34 GMT. --
Apr 20 20:37:59 raspberrypi satnogs-client[23128]: satnogs
- INFO - Post data started
Apr 20 20:38:59 raspberrypi satnogs-client[23128]: satnogs
- INFO - Trying to GET observation jobs from the network
Apr 20 20:39:59 raspberrypi satnogs-client[23128]: satnogs
- INFO - Trying to GET observation jobs from the network
Apr 20 20:40:59 raspberrypi satnogs-client[23128]: satnogs

```

2

Schedule a new observation (whatever is next available to schedule) from your station's dashboard online. Keep watching the logs, when the client tries to perform the next observation, if there is a problem it should be recorded here. Copy and paste the logs and send them in an email to Nico Carver: ncarver@cfa.harvard.edu



APPENDICES

- A. Alternative method for preparing the MicroSD Card with dd
- B. Brief Introduction to Satellite Communication
- C. Glossary of technical terms and acronyms
- D. Activities

A. ALTERNATIVE METHOD FOR PREPARING THE MICROSD CARD WITH `dd`**Parts**

3. SD Card

**Tools**

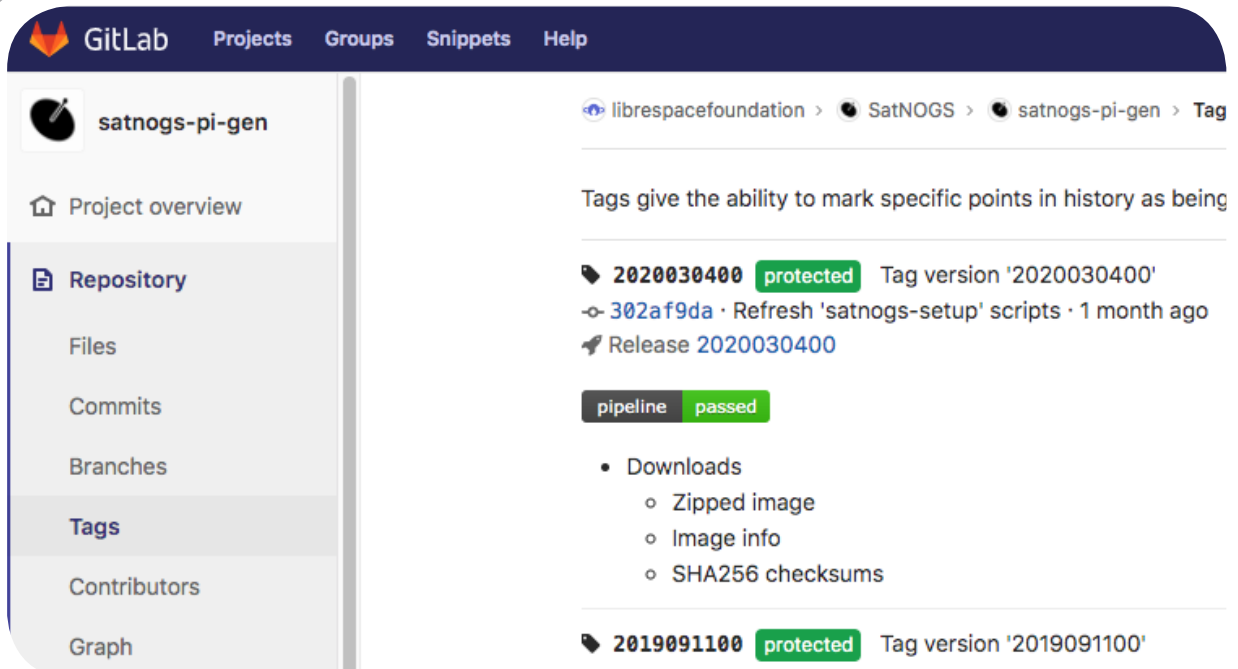
8. MacBook

9. USB C Hub Adapter

1

Open a web browser, and go to this page on the SatNOGS GitLab where you will find the latest release of the SatNOGS Raspbian image at the top of the page:

<https://gitlab.com/librespacefoundation/satnogs/satnogs-pi-gen/-/tags>



2

Each release will have three downloads. We only need to download the “Zipped Image”. Click on the word “Zipped Image” on the most recent release to download it. The file will take a few minutes to download. The other two files in the Downloads list are text files with information about the image that you can download if interested.

librespacefoundation > SatNOGS > satnogs-pi-gen > Tags

Tags give the ability to mark specific points in history as being important

2020030400 **protected** Tag version '2020030400'

302af9da · Refresh 'satnogs-setup' scripts · 1 month ago

Release 2020030400

pipeline **passed**

- Downloads

- Zipped image**

- Image info

- SHA256 checksums

2019091100 **protected** Tag version '2019091100'

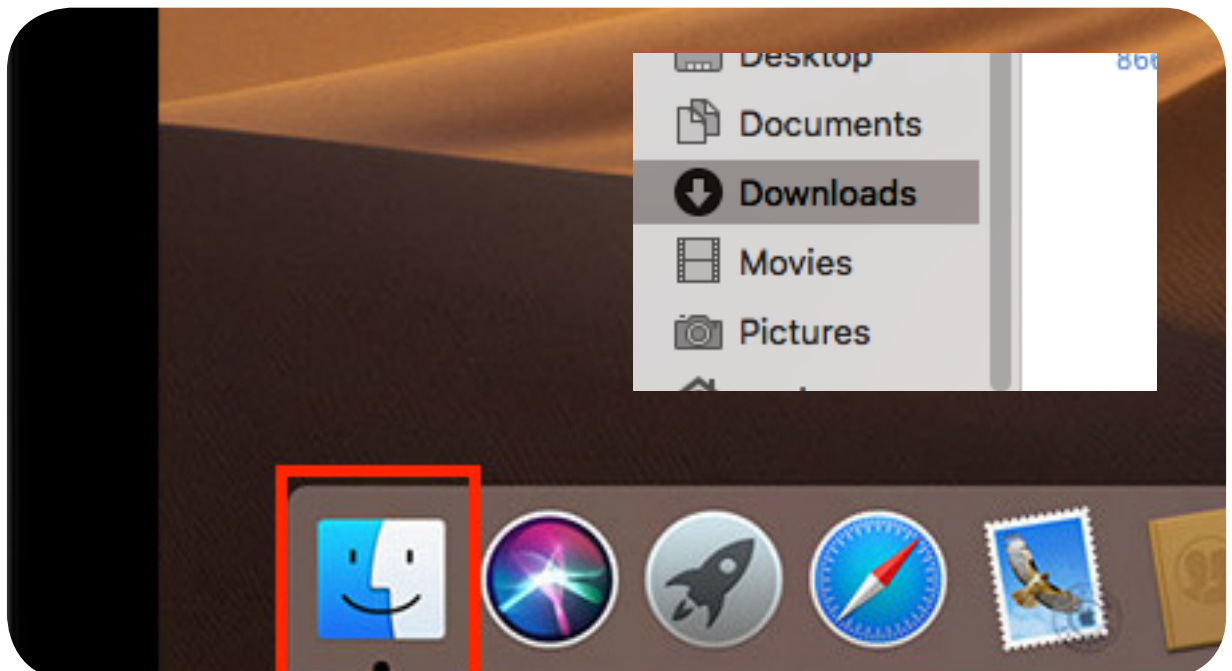
81052ae8 · Use POSIX compatible 'read' arguments · 7 months ago

Release 2019091100

pipeline **passed**

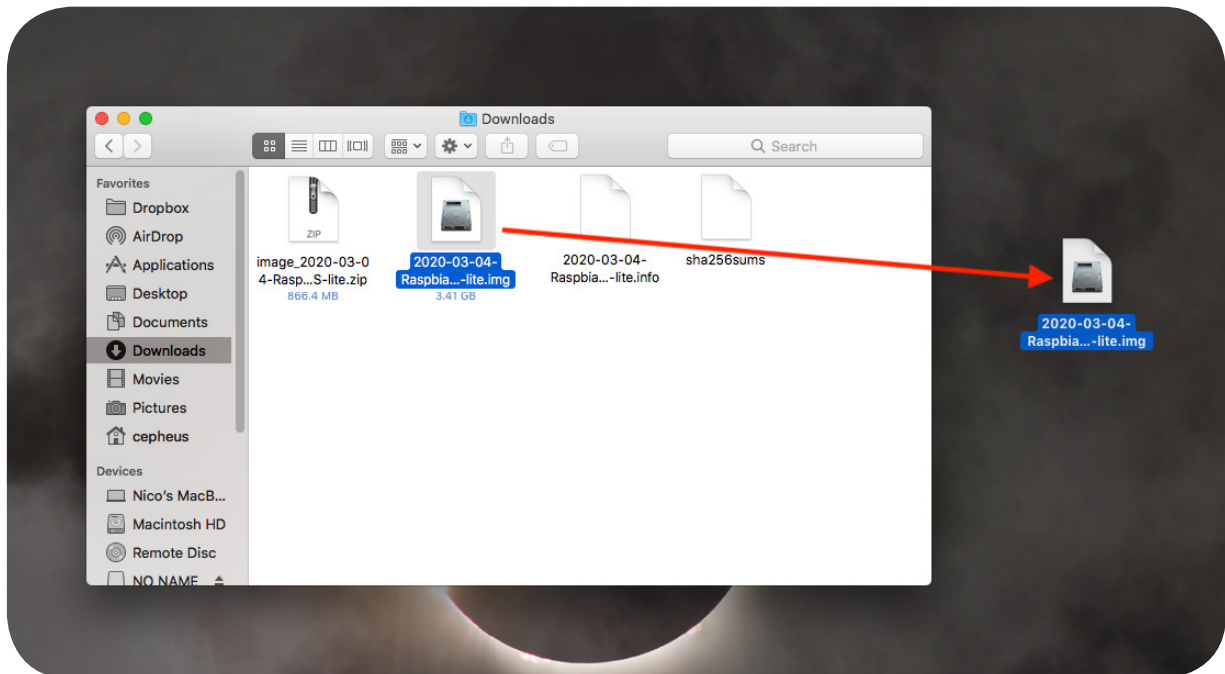
3

Navigate to the “Downloads” folder on your computer. If using a Mac, click the Finder icon and then “Downloads” should be on the left-hand side of the Finder window.



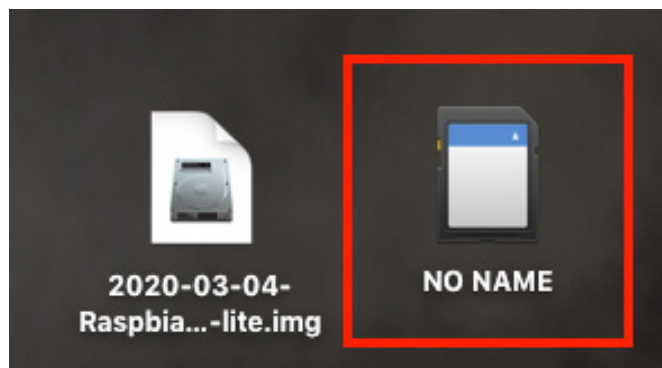
4

Drag the .img file to the Desktop.



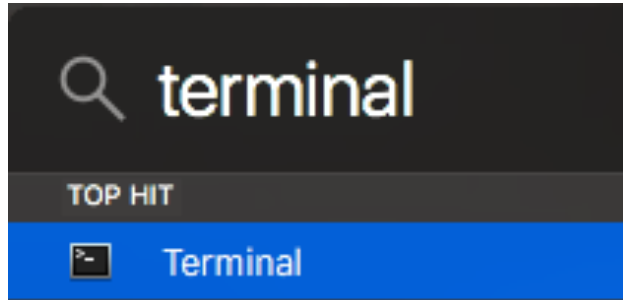
5

Insert the microSD card (Part 3) into the included SD Card Adapter, and then insert the SD Card (upside down) into the USB Hub Adapter (Tool 9) connected to the Macbook (Tool 8). You should see it appear on the Desktop as NO NAME.



6

Click the magnifying glass in the upper-right corner, type in Terminal, and press Return.



7

Type the command:

`diskutil list`

and press Return. Find NO NAME and note what disk it is. Typically, if you have no other drives connected, it should be `/dev/disk2`, but please make sure this is the case.

```
/dev/disk0 (internal, physical):
#:              TYPE NAME                    SIZE       IDENTIFIER
0:      GUID_partition_scheme                *751.3 GB   disk0
1:                   EFI EFI                  209.7 MB    disk0s1
2:          Apple_APFS Container disk1        751.1 GB    disk0s2

/dev/disk1 (synthesized):
#:              TYPE NAME                    SIZE       IDENTIFIER
0:      APFS Container Scheme -               +751.1 GB   disk1
                       Physical Store disk0s2
1:          APFS Volume Macintosh HD           80.4 GB     disk1s1
2:          APFS Volume Preboot                 33.1 MB     disk1s2
3:          APFS Volume Recovery                516.2 MB    disk1s3
4:          APFS Volume VM                      3.2 GB      disk1s4

/dev/disk2 (internal, physical):
#:              TYPE NAME                    SIZE       IDENTIFIER
0:      FDisk_partition_scheme                *32.0 GB    disk2
1:          Windows_NTFS NO NAME              268.4 MB    disk2s1
2:              Linux                        3.1 GB      disk2s2

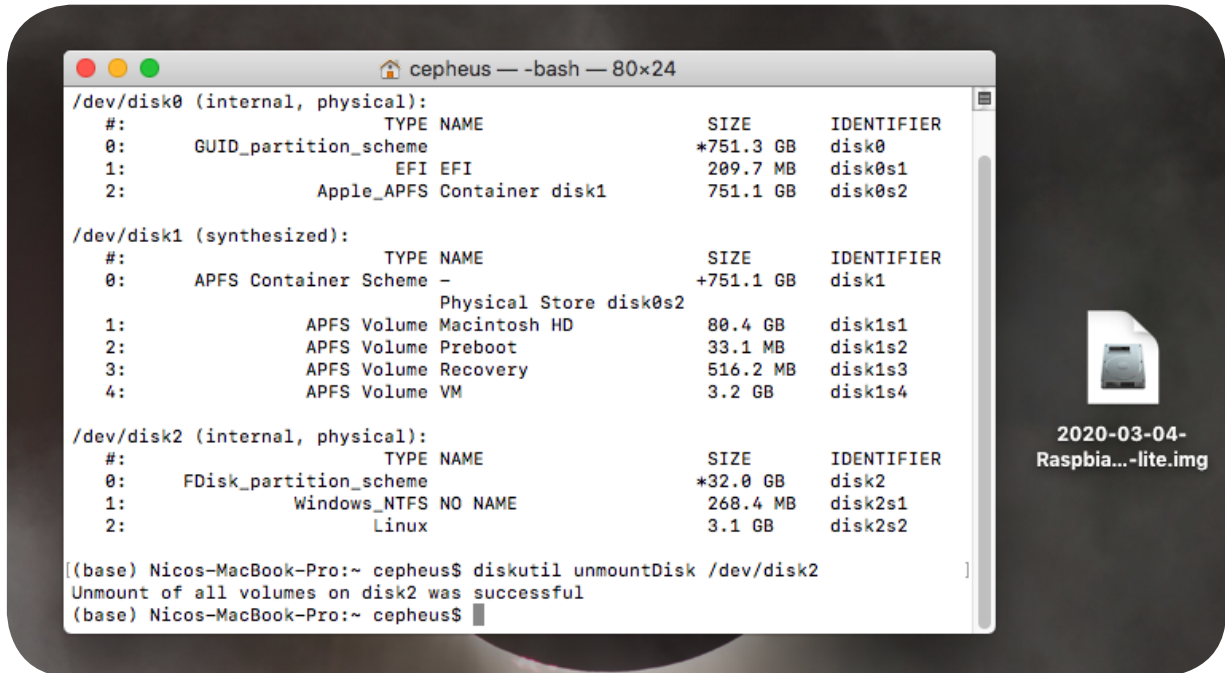
(base) Nicos-MacBook-Pro:~ cepheus$
```

8

Type the command:

```
diskutil unmountDisk /dev/diskN
```

replacing N with the disk number identified in step 7. Press Return to execute the command. The SD card “NO NAME” will disappear from the desktop after this step.

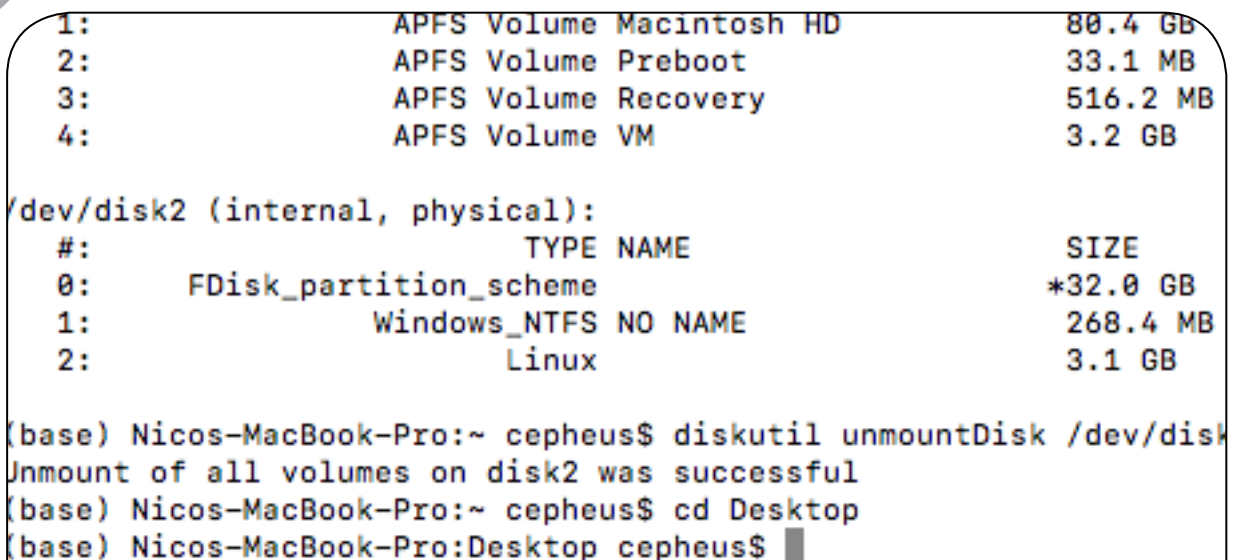


9

Type the command:

```
cd Desktop
```

to change your working directory to the Desktop. Press Return to execute the command.



Type the command:

```
sudo dd bs=1m if=2020-03-04-Raspbian-SatNOGS-lite.img  
of=/dev/rdiskN conv=sync
```

replacing the N after disk with the number identified in step 7. Also, double-check the name of the img file and make sure that it matches to the file name above. If not, use the file name on your computer. Press Return to execute. If asked for a password, use the password you use to log in to the computer, and press Return again. Note: the command line will not show you typing your password indicated by ********* as is typical with websites.

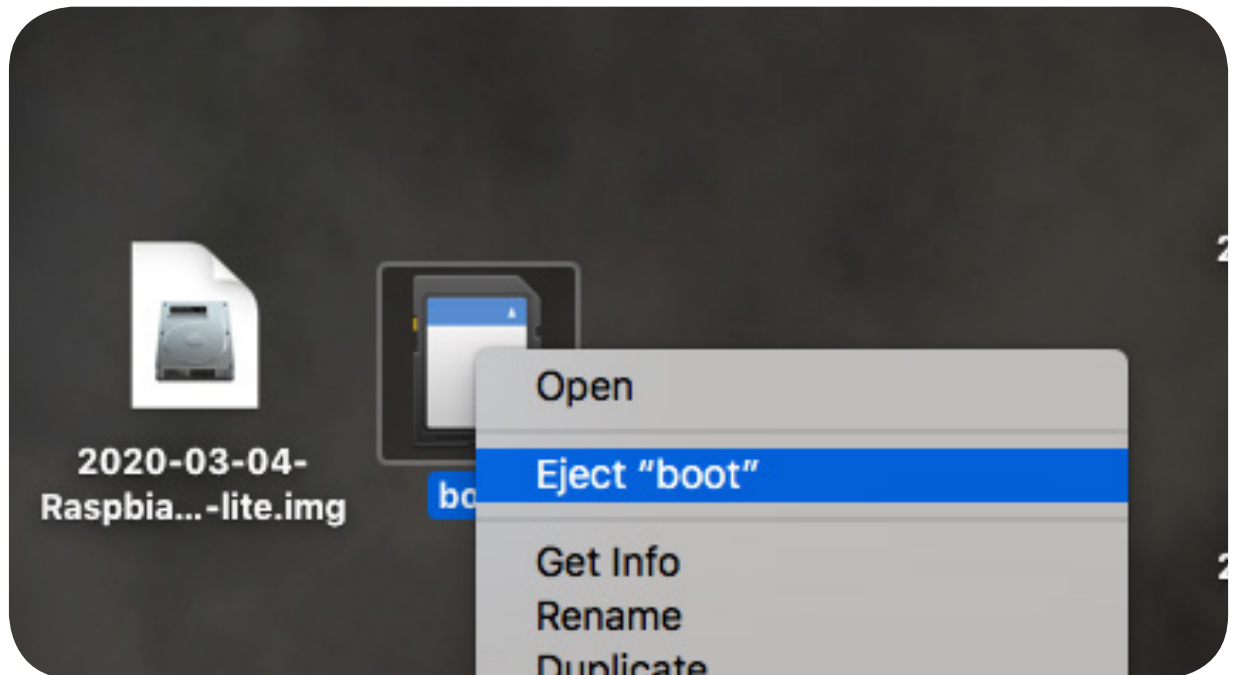
```
Macintosh HD      80.4 GB      disk1s1
  Volume Preboot   33.1 MB      disk1s2
  Volume Recovery  516.2 MB     disk1s3
  Volume VM        3.2 GB      disk1s4

al):
TYPE NAME          SIZE      IDENTIFIER
Name             *32.0 GB   disk2
NTFS NO NAME      268.4 MB  disk2s1
Linux            3.1 GB    disk2s2

cephus$ diskutil unmountDisk /dev/disk2
disk2 was successfully unmounted
cephus$ sudo dd bs=1m if=2020-03-04-Raspbian-SatNOGS-lite.img of=/dev/rdisk2 conv=sync
```

11

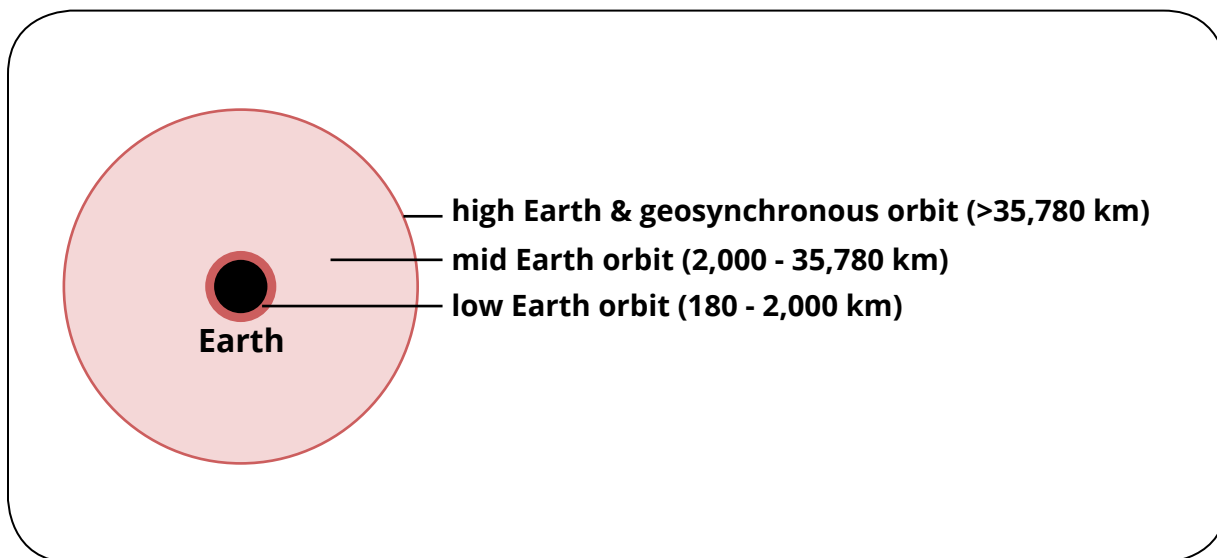
When complete, the SD Card will re-mount to the Desktop as “boot”. Right-click->Eject (or drag to the Trash) to safely eject the card. You can now remove the MicroSD Card, and continue with the Build.



B. BRIEF INTRODUCTION TO SATELLITE COMMUNICATION

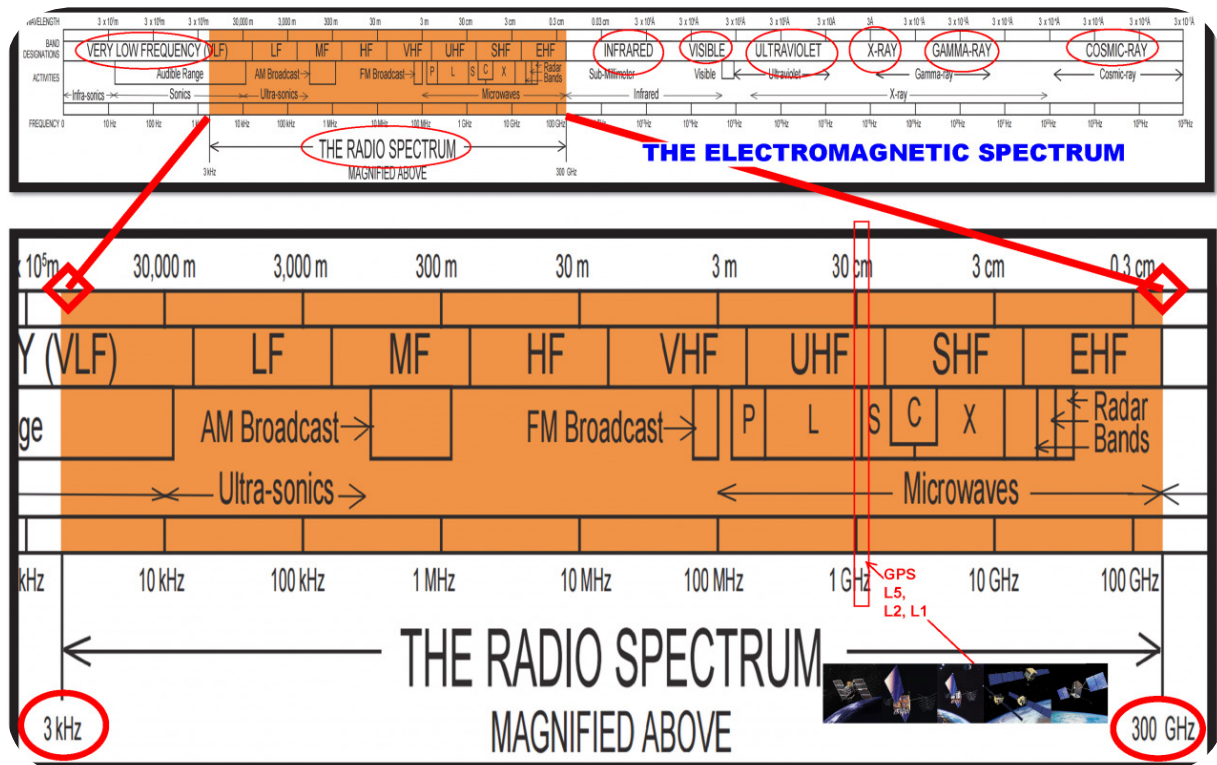
Orbits

Satellites are designed by teams of engineers and scientists with a particular mission in mind, such as monitoring Earth's weather events, testing a new battery in space, recording gravitational waves, etc. They are launched into space as cargo, and deployed at a specific orbit. Most of the satellites we can track with SatNOGS ground stations are in low Earth orbit meaning they are between 180 and 2,000 kilometers high, and orbit the Earth every 90 minutes! It is much less expensive to launch a satellite into low Earth orbit than some of the higher orbits, like a geostationary orbit at 35,780 kilometers above Earth. A geostationary satellite's orbital period is 24 hours, meaning from an observer (or ground station) on Earth it would appear as if the satellite is not moving. Geostationary satellites don't require ground station networks because their position is fixed. Low Earth orbit satellites move so fast that it helps to have a 'rotator' built in to the ground station that will track the satellite and move the antenna as the satellite moves quickly across the sky.



Frequencies

Every satellite communicates at a particular radio frequency (think of receiving different stations on the FM radio in your car), and different types of antennas are needed on ground stations to pick up communications from different kinds of satellites. Most amateur satellites and the NOAA weather satellites operate in VHF/UHF, which is a range of frequencies shared by many terrestrial sources such as FM radio, TV broadcasts, cellular phones, etc. Scientific missions increasingly favor higher frequencies such as S, C, and X bands because these areas of the radio spectrum are less trafficked and it is possible to send more complex data back at these higher frequencies.



C. GLOSSARY OF TECHNICAL TERMS AND ACRONYMS

70cm-Band Part of the radio spectrum that ranges from 420 to 450 megahertz (MHz) often used by radio amateurs. Many amateur satellites downlink between 435 and 438 MHz because this frequency range is reserved for their use.

C-Band Part of the radio spectrum that ranges from 4 to 8 gigahertz (GHz).

Cfa Center for Astrophysics | Harvard & Smithsonian. Located in Cambridge, MA, USA. This is the parent institution of the Wolbach Library.

<https://www.cfa.harvard.edu>

Client (Software) A Client is software that connects to software running on a server over a network. This relationship is called a client-server model. In the context of the LSTN ground station, the SatNOGS client software running on a Raspberry Pi is in constant communication with software running on the SatNOGS network (the server) in order to function properly. It is through this model, that a station owner can operate their station on the SatNOGS website.

CubeSat A small satellite that is made up of any multiple of cubes that are all 4 in × 4 in × 4.5 in. Each cube is one unit (U) of the CubeSat. For this reason, the size of the satellite is expressed like so: 1U, 3U, etc.

Directional antenna An antenna that receives stronger signals in the direction that it is pointed. For tracking satellites, this type of antenna is often paired with a rotator.

Downlink To transmit from a spacecraft (e.g. satellite) to a ground station.

GEO Geostationary Earth Orbit. Earth-centered orbit with an altitude of approximately 35,786 kilometers.

Ground station A station on Earth that receives communication from an orbiting satellite.

Hertz (Hz) This describes the frequency of a wave. 1 hertz = 1 cycle per second. Radio frequencies range from 3 kHz (3,000 cycles per second) to 300 GHz (300 billion cycles per second).

L-Band Part of the radio spectrum that ranges from 1 to 2 gigahertz (GHz).

LEO Low Earth Orbit. Earth-centered orbit with an altitude between 180 and 2,000 kilometers.

LNA Low Noise Amplifier. This is put between the antenna and the radio and amplifies the relatively weak signal from the satellite.

LSF Libre Space Foundation. A non-profit foundation that leads a number of open source space technology projects including SatNOGS. LSF has partnered with the Wolbach Library on the LSTN pilot. They are headquartered in Greece.

<https://libre.space>

LSTN Library Space Technology Network. A program to make space technology more accessible through a network of ground stations in public libraries.

<https://lstn.wolba.ch>

MetaSat An open metadata schema for small satellite missions. This is a related project that is also being led by the Wolbach Library. <https://schema.space>

Omnidirectional Antenna An antenna that receives signals equally from all directions.

PoE Power over Ethernet. Passing power along with data through an Ethernet cable.

Radio A device that receives radio waves and makes them usable by a computer or person.

Rotator Piece of hardware that can change the orientation of an antenna.

Raspberry Pi A small computer (4 x 3 inches) used in many DIY electronics projects due to its small size, lower power requirements, and price (\$35).

RF Cable Radio Frequency Cable. A cable that transmits radio frequency signals. They are a type of coaxial cable.

SatNOGS Open Source global network of satellite ground-stations operated by the Libre Space Foundation (LSF).
<https://satnogs.org>

Satellite A human-made object placed in orbit around either the Earth or another body (interplanetary satellites).

S-Band Part of the radio spectrum that ranges from 2 to 4 gigahertz (GHz). Has been used extensively by satellites with science missions.

SDR Software-defined radio. A radio where many of the components that make up a radio are now software-based rather than hardware-based. This has decreased costs for doing sophisticated radio communication.

Server A server is a computer that operates in a server-client model over a network where multiple clients can request resources and send communications to a centralized server. This is how the SatNOGS Network operates.

UHF Ultra high frequency. Part of the radio spectrum that ranges from 300 MHz to 1 GHz.

Uplink To transmit from a ground station to a spacecraft (e.g. satellite).

UTC Coordinated Universal Time. The time standard for the world. All time zones can be expressed as hours before or after UTC (e.g. UTC-5 or UTC+13). Satellite tracking is all done in UTC.

VHF Very high frequency. Part of the radio spectrum that ranges from 30 to 300 MHz.

X-Band Part of the radio spectrum that ranges from 8 to 12 gigahertz (GHz). More advanced ground stations are needed, but this band is increasingly being used for science missions.

D. ACTIVITIES

We have several ideas for community-based activities for your LSTN ground station. These are still being developed and will be sent to you in a future mailing to include here.