BINARX
SATNOGS GROUND STATION KIT

This guide walks students through setting up their very own SatNOGS ground station, enabling them to track satellites in Low Earth Orbit (LEO) with a manual Yagi antenna.

The aim is to have the students assemble and configure the kits themselves, but support from your IT department will be required to set up the internet connection at individual schools.

MISSION PHASE	SKILL AREA	AUDIENCE	LAST UPDATED
Phase E	Operations & Sustainment	School Years 7-10	26/02/2025

WARNINGS:

The supplied junction boxes are water resistant, not waterproof! Do not allow electrical connections to be exposed to water.

Do not operate your ground station if it is raining, ESPECIALLY not if there is a Lightning storm.

Do NOT run your SDR with the Bias-T power enabled unless it is connected to the Low Noise Amplifier and a suitable antenna (such as the handheld Yagi supplied in the kit). Doing so will damage and possibly break your SDR. You'll know when the Bias-T Power is on when you see the LED turn on your Low Noise Amplifier.

The instructions on correctly connecting the SMA connectors for this step and any following connections are written on pages 10-11. This is important to prevent damaging the connectors

Setup Instructions (with included Handheld Yagi Antenna)

Parts Provided (by BinarX Program):

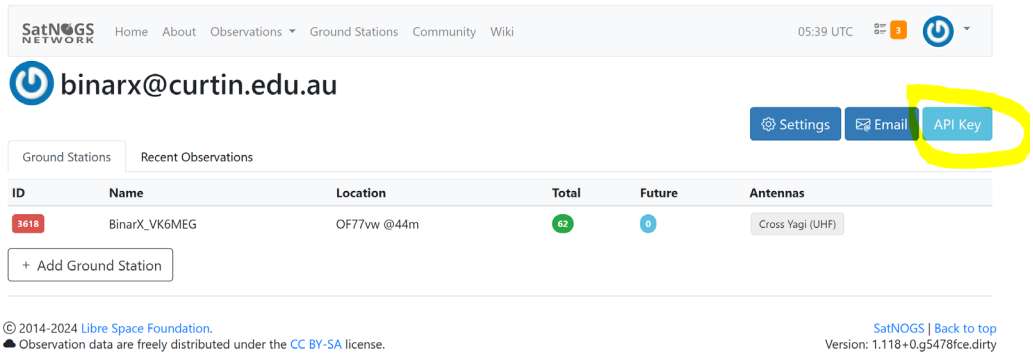
1. Raspberry Pi 4 Model B 1GB (Single Board Computer)
2. 3D Printed Case for Raspberry Pi
3. Fixings for 3D Printed Case
4. MicroSD Card (32GB)
5. USB-A/C Micro SD Card Reader
6. 12.5W USB-C Power Supply for Raspberry Pi
7. USB Extension Cable (Adafruit Accessories Snap-In Panel Mount Cable)
8. HDMI to Micro HDMI Adapter
9. RTL-SDR Blog V3 Software Defined Radio (SDR)
10. Handheld Yagi UHF Antenna (420-450MHz)
11. SMA to UHF Handheld Antenna Cable (20cm)
12. SMA Male to SMA Male Coaxial Extension Cable (3m)
13. Low Noise Amplifier (Nooelec Lana LNA with Bias Tee)
14. Ferrite Core Filters (for noise suppression)
15. Weather-resistant Junction Box for Raspberry Pi + SDR
16. Weather-resistant Housing for LaNa Low-Noise Amplifier with cable glands pre-installed

Additional Parts/Elements the School Will Need to Provide:

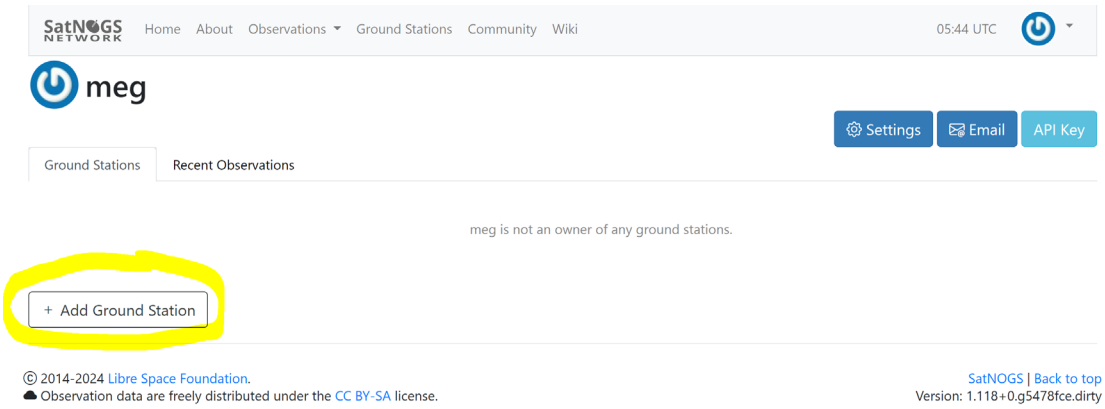
1. HDMI Cable (for connecting Raspberry Pi to monitor)
2. Monitor with HDMI Port (to set up and configure the Raspberry Pi)
3. USB Keyboard (to input commands on the Raspberry Pi)
4. Internet-connected WiFi network (to connect the Raspberry Pi to the SatNOGS network) - noting that a hard-wired ethernet connection is fine too, but you'll need to supply your ethernet cable
5. Smartphone or Tablet with Stellarium App (to track satellite passes for manual adjustments of the Yagi antenna)
6. Computer with available USB-A or USB-C Port
7. Extension Cables for Power (if power sources are further from the setup)

Step-by-Step Setup – Please have the students do this themselves, with IT or a teacher to assist with setting up the wireless or wired internet connection. If there are any issues with the kit for your school, please contact us at binarx@curtin.edu.au so we can help you find a workaround if necessary

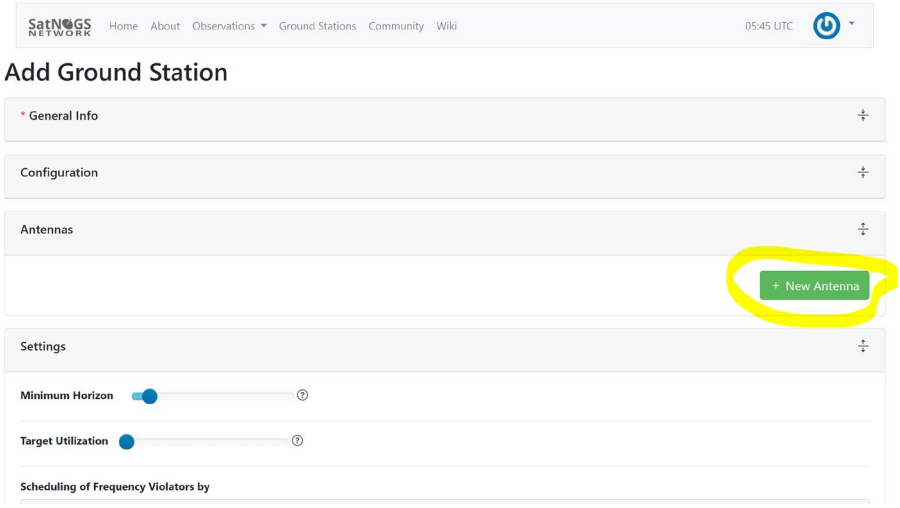
1. **Set up an account on the SatNOGS Network:**
    a. Before you can start using your ground station, you'll need to set up an account on the SatNOGS network
    b. https://network.satnogs.org/accounts/signup/
    c. Take note of your API key; you'll need this to set up your Raspberry Pi with the custom SatNOGS image (see next step).
        i. If you need to find your API key again, you can log in to your account and click on the API Key button. (Note: don't hit renew, or you'll have to update the settings on your Raspberry Pi



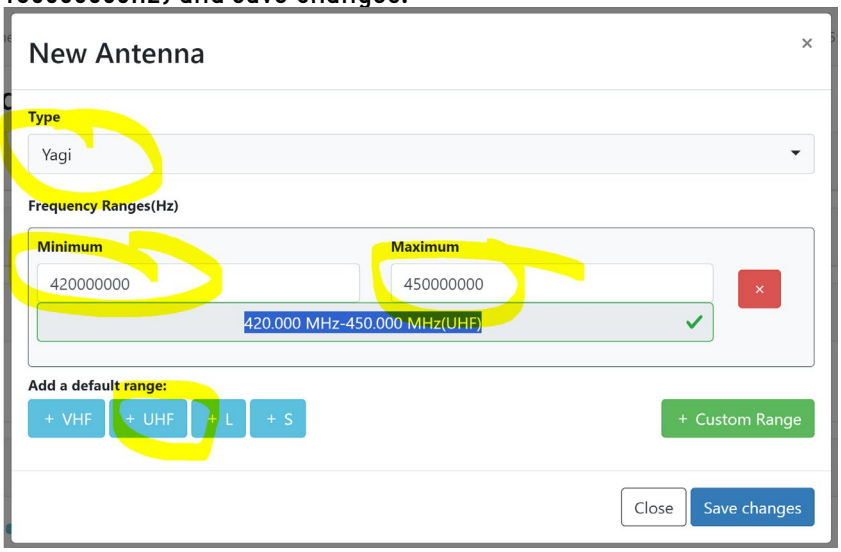
    d. Click on "Add Ground Station"



    e. Fill out the information for your ground station location. Click on "New Antenna"



i. If you're using the handheld Yagi antenna we supplied you, select Type › Yagi, with a frequency range of 420 MHz – 450 MHz (i.e. 420000000–450000000Hz) and save changes.



f. Fill in any other info you want or add images, and when you're done, scroll to the bottom and click "Submit".

2. You will get a verification email using the email you supplied; please ensure you verify your SatNOGS account using that email.

Preparing the MicroSD Card

a. On a computer with an SD card reader, download the **Raspbian SatNOGS Image:** SatNOGS.img.gz from the BinarX GitHub fromhttps://github.com/BinarX-Curtin/BinarX-SatNOGS-GroundStation/tree/main/SatNOGS_ImageUnzip / extract the file. You should see another file called satnogs.img. Place this file somewhere easy to find.
b. Place the microSD card into the SD card adapter and insert it into your computer.
c. Next, we will flash the SatNOGS image onto the microSD card using Raspberry Pi Imager.
    i. Raspberry Pi Imager: https://www.raspberrypi.com/software/
d. Open Raspberry Pi imager on your device.
e. Under "Raspberry Pi Device", select "Raspberry Pi 4"
f. Under the "Operating System" menu, scroll down until you find "Use custom". Locate where you stored the image file, select it, and press "open".
g. Finally, select your microSD card under the "Storage" menu.

h. Once this has been done, press next and wait for the “Use OS customization” dialogue box. Select “Edit Settings”
i. Tick the “Set username and password” box and then enter the username and password you want to set for the Raspberry Pi.
    i. Note: It’s very important that you remember this!
j. Under the “Services” tab, tick the “Enable SSH” box and select “Use password authentication”.
k. Click “Save” and then click “Yes” when prompted.
l. Click “Yes” again if you are prompted to remove all data on the microSD card.
m. Wait until the image is successfully flashed.

3. Assembling the Raspberry Pi
    a. Put the Raspberry Pi into the 3D Printed Case. Make sure the USB ports align with the cutouts of the top panel.
    b. Secure it using the provided fixings.

4. Setting Up and Configuring the Raspberry Pi
    a. Connect the HDMI Cable from the Raspberry Pi to the Monitor
    b. Plug the USB Keyboard into the Raspberry Pi.
    c. Insert the SD Card into the Raspberry Pi. This card should now contain the necessary software (Raspbian OS, SatNOGS client).
    d. Connect the 12.5W Micro USB Power Supply to the Raspberry Pi to power it on.
    e. To set up the image, first type in the username and password you set before.
    f. Next, you will need to set up an internet connection.
        - Note that you’ll need help from your teacher or IT department, especially to set up the WIFI or hardwired connection to the internet. If this isn’t possible, please let us know at binarx@curtin.edu.au so we can support you in finding a workaround.
    g. After you are connected to the internet, type in the following:
        `satnogs-setup`
    h.
    i. Once entered, you will see a screen with text and a blue background. You will use your arrow keys to navigate the menu. Click enter when selecting “Basic”
    j. Make sure “SATNOGS_API_TOKEN” is selected, copy your API key in and select “Save”
    k. Under “SATNOGS_STATION_ELEVATION”, type in your elevation above sea level and select “Save”
    l. Under “SATNOGS_STATION_ID”, type in your station ID (the 4 numbers on the dashboard next to your ground station!), and select “Save”
    m. Under “SATNOGS_STATION_LAT”, type in your current latitude and select “Save”. Repeat this for longitude.
    n. Once this is all done, navigate to the “‹Back›” button and select it, then repeat this again for the “‹Exit›” button.

5. Connecting the SDR to the Raspberry Pi
    a. Plug the RTL-SDR V3 SDR Dongle USB Extension Cable to extend the reach of the SDR adapter.
    b. Plug the USB Extension Cable into one of the Raspberry Pi’s USB ports.

6. Setting Up the Yagi Antenna and Low Noise Amplifier (LNA)
    a. Unfold the Yagi-U Antenna (420-450 MHz).
    b. Feed the SMA-to-UHF cable into one of the glands on the supplied small weather-resistant box (with the clear top)
    c. Warning: Incorrectly connecting radio connectors may damage or break the connectors. Note that the instructions on how to correctly connect the SMA connectors for this step and any following connections are written on Pages 10-11

d. Connect the SMA-to-UHF cable (20cm) from the Yagi Antenna to the Nooelec Lana LNA (into the side of the LNA marked INPUT)
e. Feed the SMA Male to Male Coaxial Cable (3m) into the remaining gland on the supplied small weather-resistant box (with the clear top), and connect it to Nooelec Lana LNA (into the side of the LNA marked OUTPUT)
f. WARNING: Do NOT run your SDR with the Bias-T power enabled unless it is connected to the Low Noise Amplifier and a suitable antenna (such as the handheld Yagi supplied in the kit). Doing so will damage and possibly break your SDR. You'll know when the Bias-T Power is on when you see the LED turn on on your Low Noise Amplifier.

7. ng the Handheld Yagi Antenna for Satellite Tracking
   a. On the SatNOGS network dashboard, under your ground station, click future passes. You can use this tool to locate and schedule satellite passes to record data from.
   b. Install the Stellarium app on a smartphone or tablet connected to the internet. This app will show you when and where satellites are passing overhead.
      i. Note: Before scheduling satellite passes, search them on the app to see if you can track them!

   c. TIP: Try starting with scheduling the International Space Station (ISS) when it has a pass – it has a nice loud signal on the FM voice repeater. It's not always transmitting, but it quite often is, so that is a good one to see if your ground station is correctly set up before trying to target quieter, smaller things like CubeSats!
   d. Note that it might be useful to check and plan for the ISS to pass overhead before trying to test the ground station, as you might have to wait a while before the ISS is above you.
   e. During satellite passes, use the app to help you point your Yagi antenna at the satellite as it tracks across the sky. (Note – don't point your phone camera or your eyes directly at the sun. If the satellite is tracking that way, it best to have a bit of a guess and follow it – you can always pick the pass up again as it gets far enough from the sun for you not to hurt your eyes)

8. Making the Setup more weather-resistant
   a. Place the Raspberry Pi and SDR inside the supplied weather-resistant junction boxes to protect them from the elements. This also makes the kit easier to move around and prevents damage.
   b. WARNING: the supplied junction boxes are water resistant, not waterproof! Do not allow electrical connections to be exposed to water.
   Do not operate your ground station if it is raining, especially if there is a lightning storm.
   c. Use outdoor rated extension cables for power if the station is far from an outlet.

9. Managing Signal Noise
   a. Attach the supplied clip-on Ferrite Core Filters to any USB or power cables to reduce interference and improve signal quality. Do not attach them to antenna cables – you don't want to block that signal!

10. Final Steps
    a. Test your setup: After the physical assembly, run a test to ensure the SDR receives signals from satellites. You can use the SatNOGS client to schedule satellite passes.

b. Track Satellite Passes: Use the Stellarium app to predict satellite passes and manually adjust the Yagi antenna for optimal reception.
    - Note that this step can be confusing and will take a lot of trial and error without specialised equipment to check if it's becoming optimal, so try to avoid this step if possible.

11. Checking Your Signal
    a. After scheduling a satellite pass on the SatNOGS dashboard and tracking the satellite, to check your results, open up the satellite observation window that was opened when you scheduled your pass.
    b. To see your data, click "Open Waterfall."

12. Optional Future Changes: Control Without a Monitor
    a. Take note of the name and username of the Raspberry Pi. You can see it on the screen shown by (name@name) (remember this!)
        i. Note: The following steps change based on your computer's operating system. Both systems must be connected to the same WiFi network as the Raspberry Pi.
    b. If you are on a Mac or Unix/Linux system, open the "Terminal" app or equivalent.
        i. Type the following into your command line (where name@name was the one you saw earlier)

            SSH name@name.local

    c. If you are on a Windows computer, you will need to install a separate app called PuTTy from https://www.putty.org/.
        i. Under "Host Name", type in the following (where name@name was the one you saw earlier)

            name@name.local

    d. You can now control the Raspberry Pi through your computer rather than with a monitor, keyboard and mouse on the Raspberry Pi!

PHOTOS OF BINARX SATNOGS GROUND STATION SETUP

(note that you may have a different box from the one shown)

Photo above: The antenna and LNA connected to the Raspberry Pi and SDR inside the weather-resistant junction box

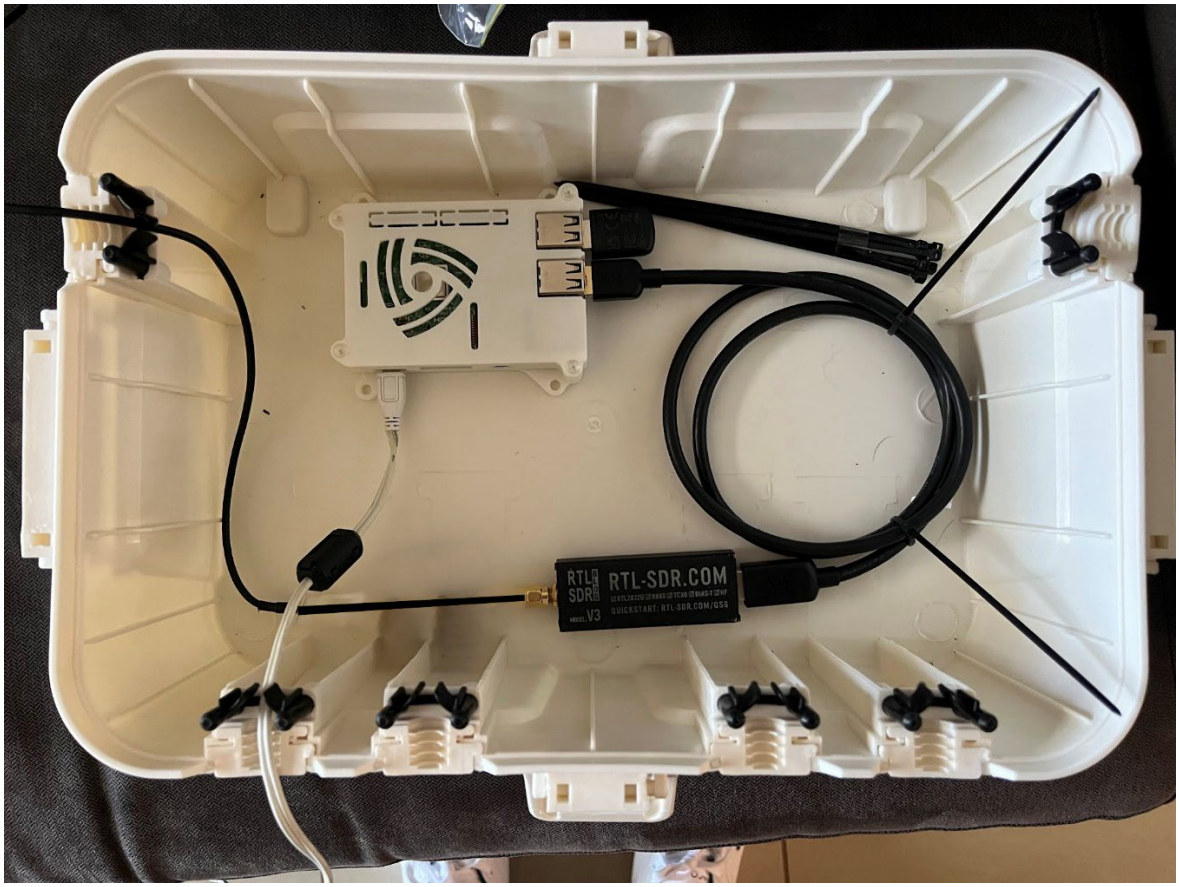
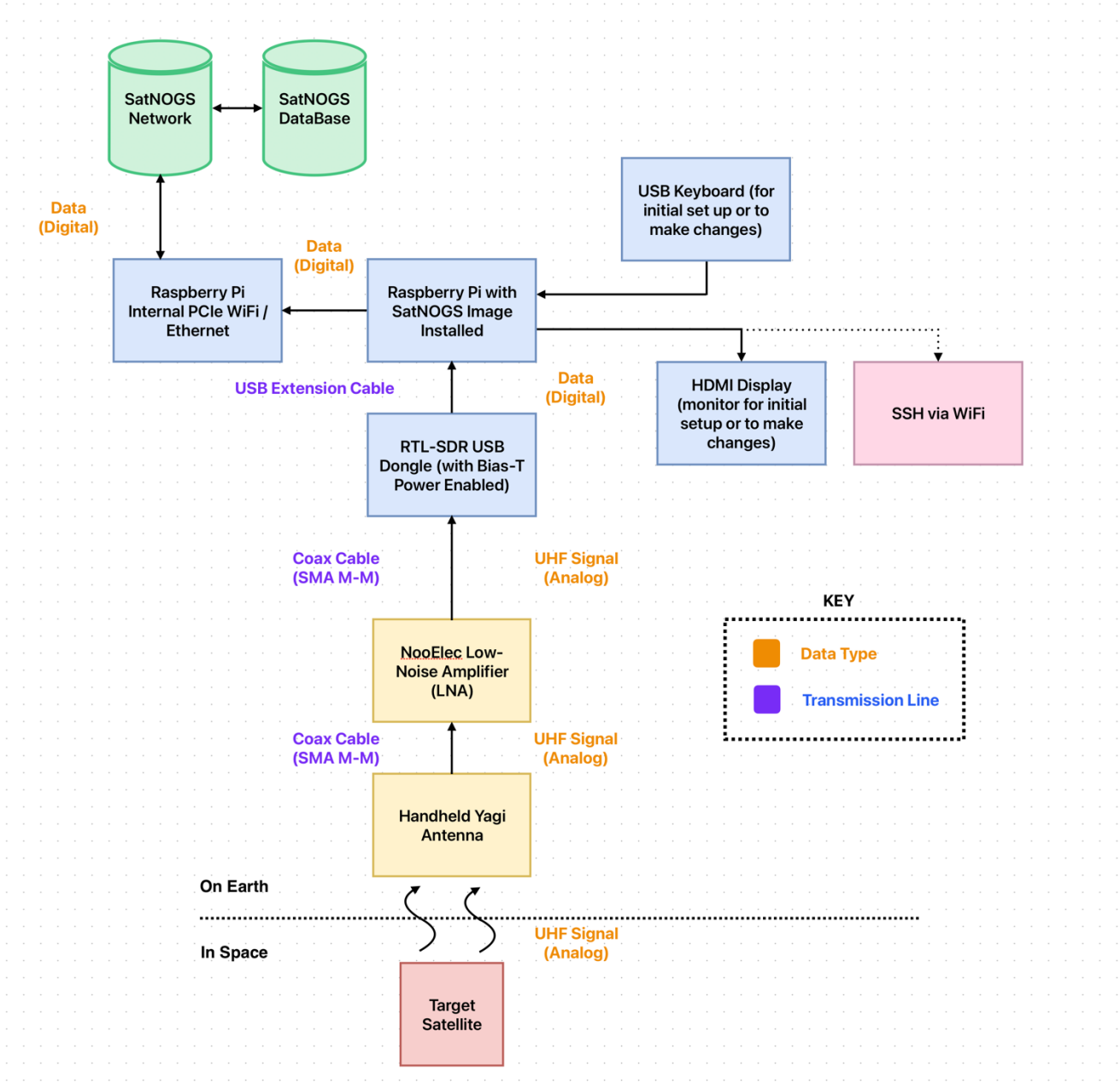


Photo above: Inside the weather-resistant junction box

	
See photo above: Note the LED on the LNA is facing towards you. If your LNA is receiving power through the Bias-T connection from your SDR, this LED will be on.	Pointing your antenna using the Stellarium app on a phone or tablet!

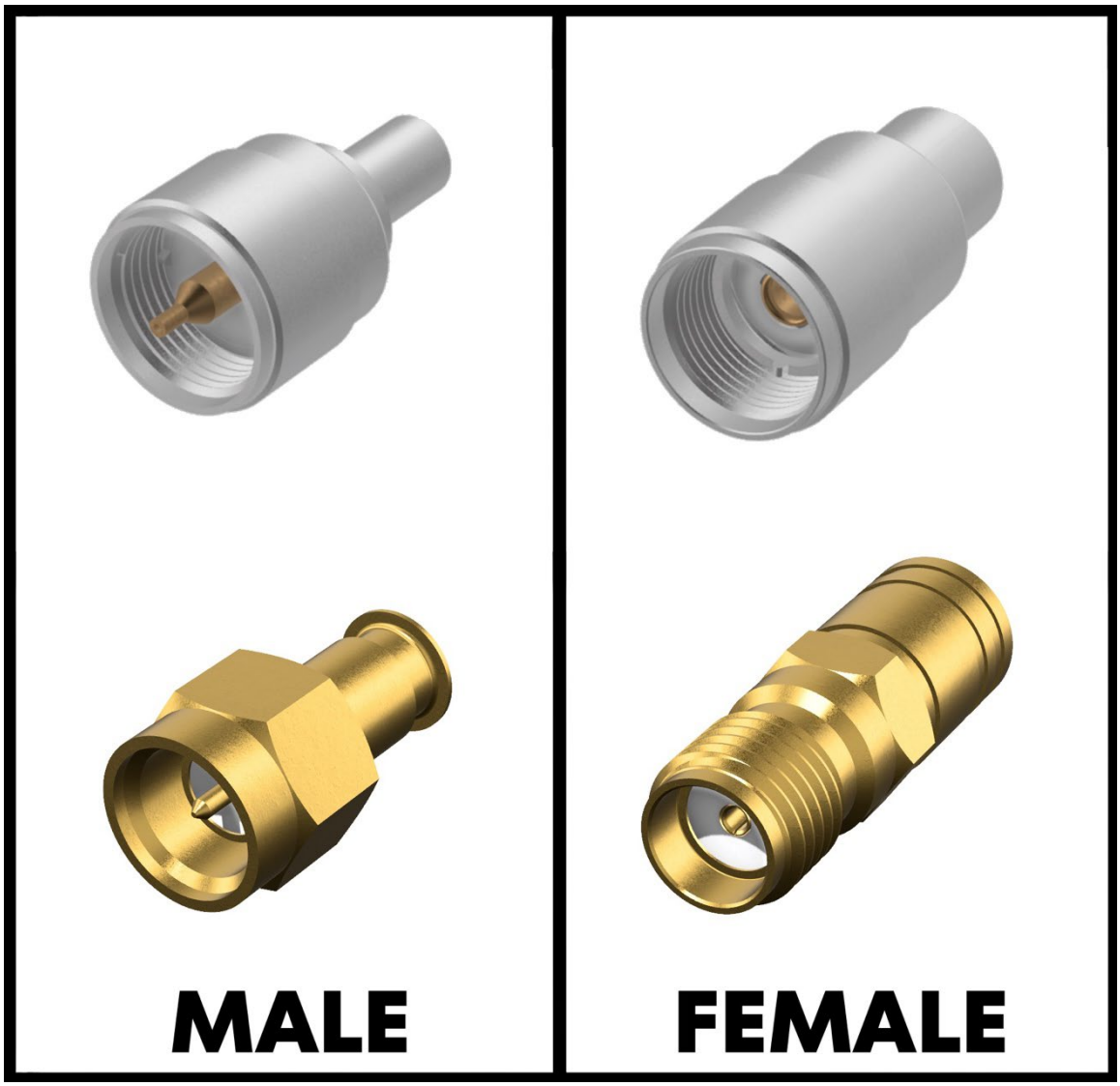
BLOCK DIAGRAM OF BINARX SATNOGS GROUND STATION SETUP



HOW TO CORRECTLY CONNECT AN SMA/UHF CONNECTOR

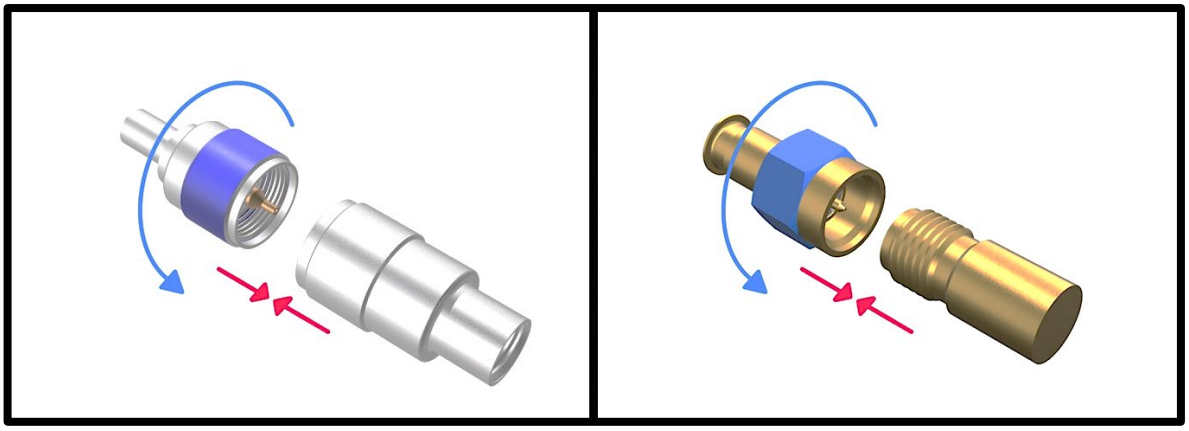
SMA/UHF Connectors are very delicate and should be taken care of when connecting and disconnecting cables. To reduce the risk of damaging the connector, a mechanism was created on the connector to allow a secure connection to be made without causing the pin in the connector to rotate and risk scratching the port or bending inside.

To connect any SMA/UHF Male to SMA/UHF Female, first locate the ports of each. The Male connector has a small pin in the centre, whilst the female connector has a port for the pin, as shown below. This is not unique to SMA connectors and will be the same for a UHF.



Once these have been found, gently line up the male connector with the female connector, making sure contact is made between the ports.

Keeping both ports still, rotate only the outer ring (highlighted in blue) on the Male connector like hand tightening a screw into the Female end to securely make an electrical connection.



LIST OF USEFUL TERMS AND DEFINITIONS

Noise: Unwanted signal that gets added in random, unpredictable patterns.

API Key: Application programming interface keys or API keys allow different software to communicate with each other without a human (you) in between.

Ferrite Core Filter: Reduces unwanted signals and noise in a certain frequency range by generating a small magnetic field that absorbs the energy from the signal generated to increase the proportion of useful signal received.

LNA / Low-Noise Amplifier: Increases the strength of low-power, weak incoming signals, making them easier to detect without adding lots of noise and unwanted signals.

Bias-T: Allows for power to be distributed through the inner conductor (I pin) of the coaxial cable. This is done by passing DC voltage through the cable to power the LNA (Low-Noise Amplifier). Without the LNA, some of the power would be reflected back into the SDR and cause damage to the sensitive electronics inside.

SDR / Software Defined Radio: A system that uses software on a computer to read, decode and demodulate radio signals rather than use physical equipment to achieve the same goal.