Cube Satellite Workshop Instruction Manual

NUS Engineering Design and Innovation Centre

Ver 1.5

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Preliminaries

This instruction manual provides a step-by-step guide to get the CubeSat kit up and running. Please read it prior to the start of your project. Each section together with the physical lab sessions are designed to help you get started but you will need to apply your own creative thinking and problem-solving skills to get it up and running. There may be multiple ways to complete the project.

Following this manual, participants will be able to:

(i) build and program an educational level CubeSat that is able to take images,
(ii) set up a “ground control station” that can communicate & control the CubeSat remotely,
(iii) measure the weight and centre of gravity of the CubeSat

When in doubt, please ask questions, but not the kind Google can help to answer.

If unsure about some connections or set up steps, please check with the course instructors during the physical sessions in the lab.

Treat the components provided to you with care. Space programs are expensive, there are usually little/or no spares so your mission will be compromised if you damage the components provided to you.

We hope you have a great experience embarking on this project and may the odds be ever in your favour. Glhf!

Course Overview

The table above provides a summary and list of steps to be taken to get the set of parts given out at the start of the course to a mock-up of a 1.5U CubeSat which communicates with your laptop as a ground station.

Setting up the Payload Computer

Items required

Here is a list of items required to get started.

Items	Remarks
Raspberry Pi 3B+	
SanDisk 32 GB Ultra Micro SD Card	
SD Card Reader	Optional, depends on PC type so that Micro SD Card may be inserted into PC
Raspberry Pi Micro-USB Power Supply	
Monitor	
HDMI Cable	HDMI on one side, and the other side depends on the input required by the Monitor used
USB Keyboard	Can be wired or wireless
USB Mouse	Can be wired or wireless

Setup and operations were tested on a PC that runs on Windows 10.

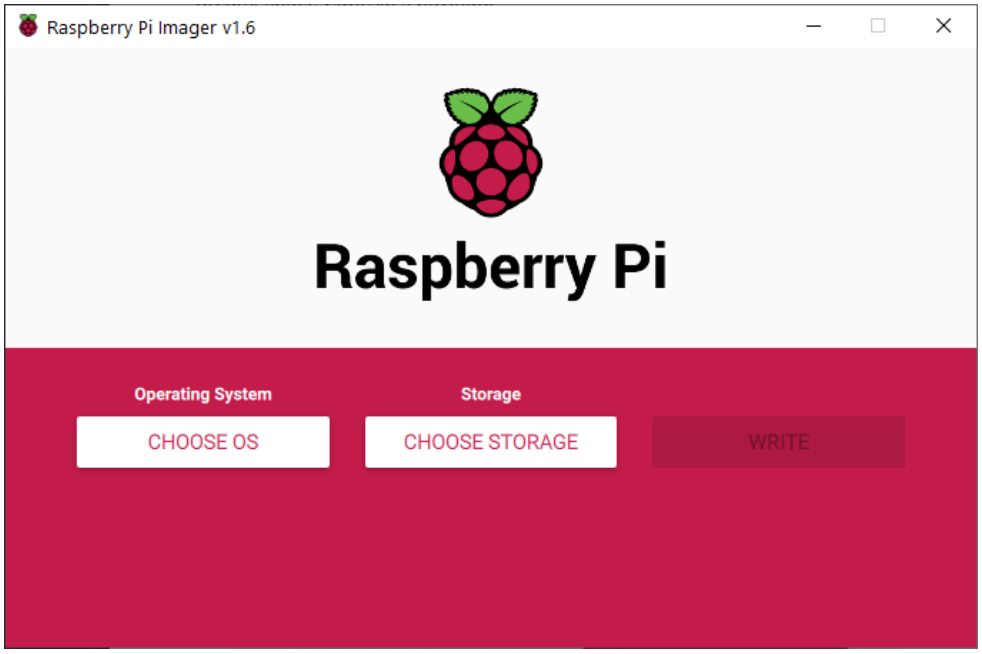
Step 1: Flashing the Raspbian OS to SD card

1. Download and install the Raspberry Pi Imager application from the website here.

   Website: https://www.raspberrypi.org/software/

2. Launch the Raspberry Pi Imager application.

   The Imager application should look like this:

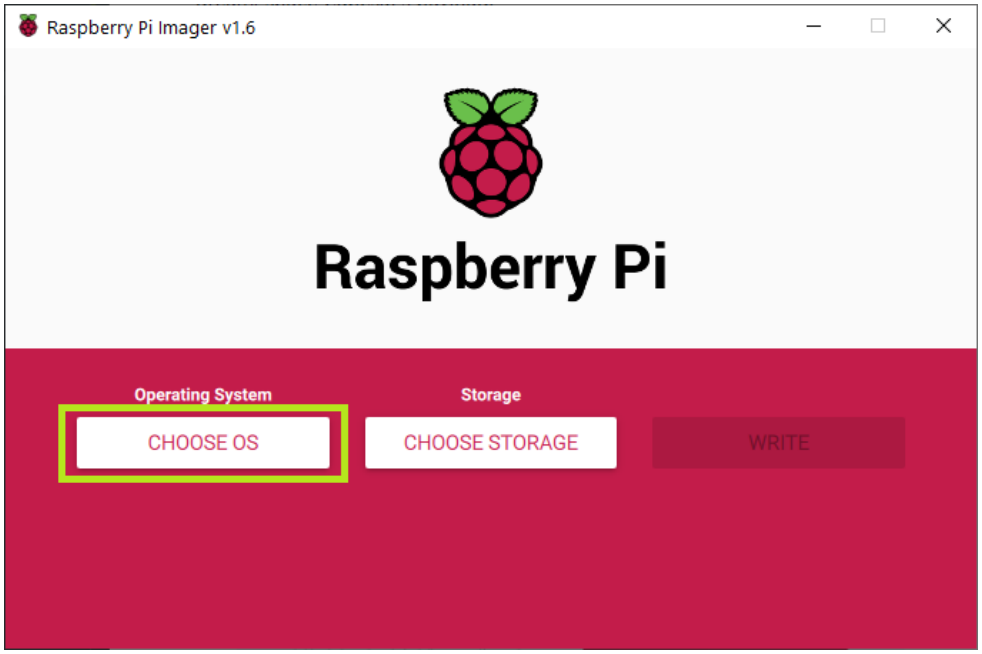


3. Download the operation system image file from https://downloads.raspberrypi.org/raspios_oldstable_armhf/images/ . Click on raspios_oldstable_armhf-XXXX-XX-XX → XXXX-XX-XX-raspios-buster-armhf.zip.

   The recommended image file should be version 2022-01-28 or earlier.

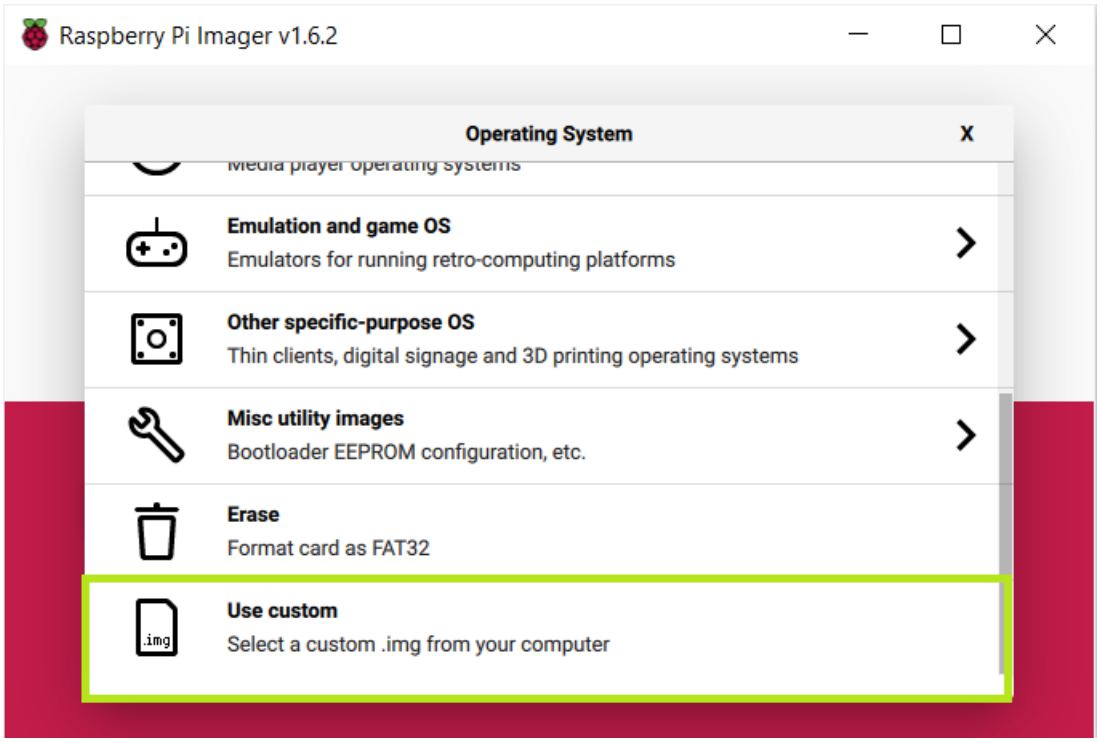
4. Click on the Choose OS button under the Operating System section.

   The Choose OS button is boxed in **green** in the image below.



5. Scroll down to select the option, Use custom.

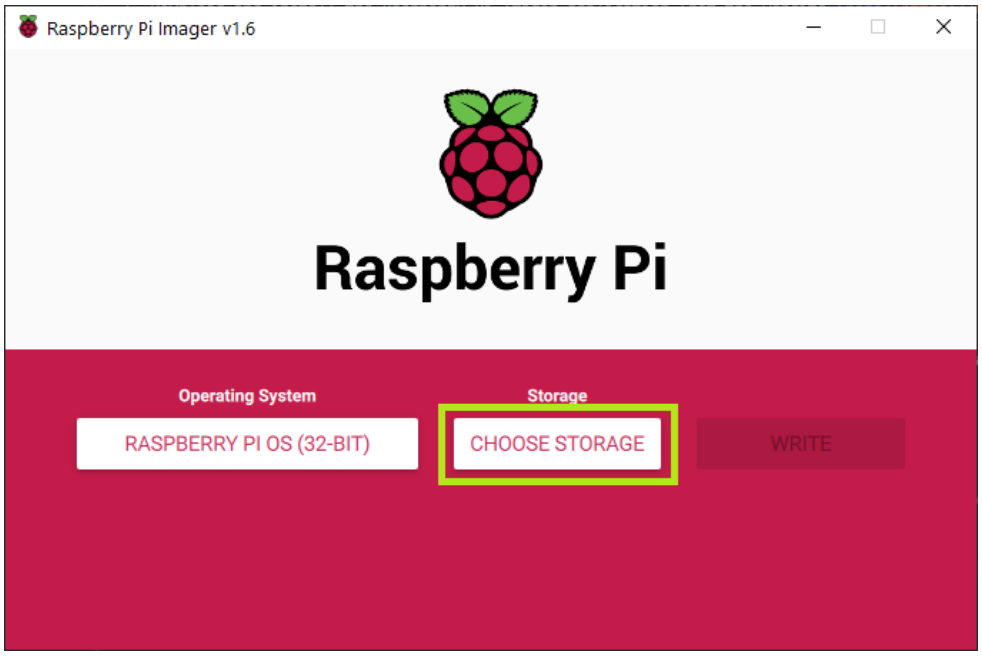
   The option to be selected is boxed in **green** in the image below.



Select the disc image file that was downloaded and unzipped in step 3.

6. Click on the Choose Storage button under the Storage section.

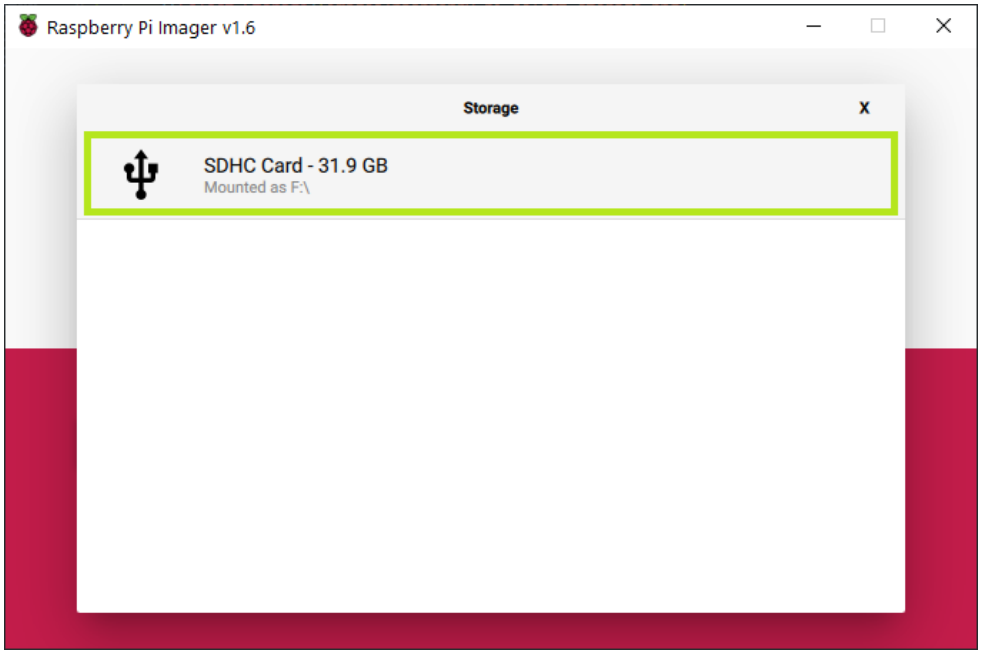
   The Choose Storage button is boxed in **green** in the image below.



7. Click on the SD Card storage to flash the OS onto.

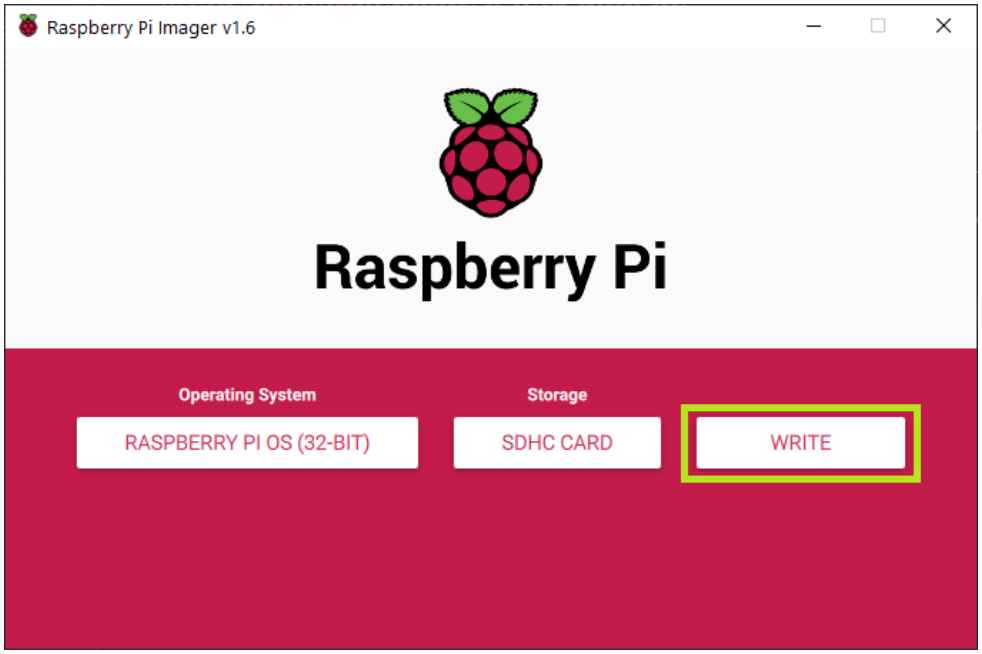
> ⚠ **To prevent overwriting your other drives, it is recommended to eject all drives before inserting the SD Card.**

8. For example, the SD Card detected is shown and boxed in **green** in the image below.



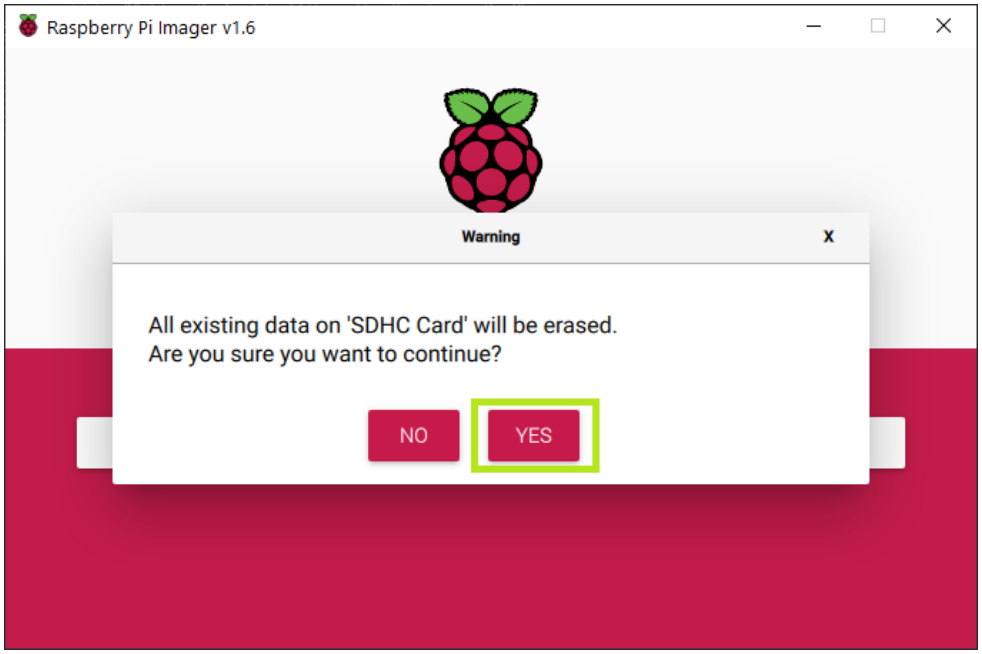
9. Click on the Write button to begin the flashing.

   The Write button is boxed in **green** in the image below.



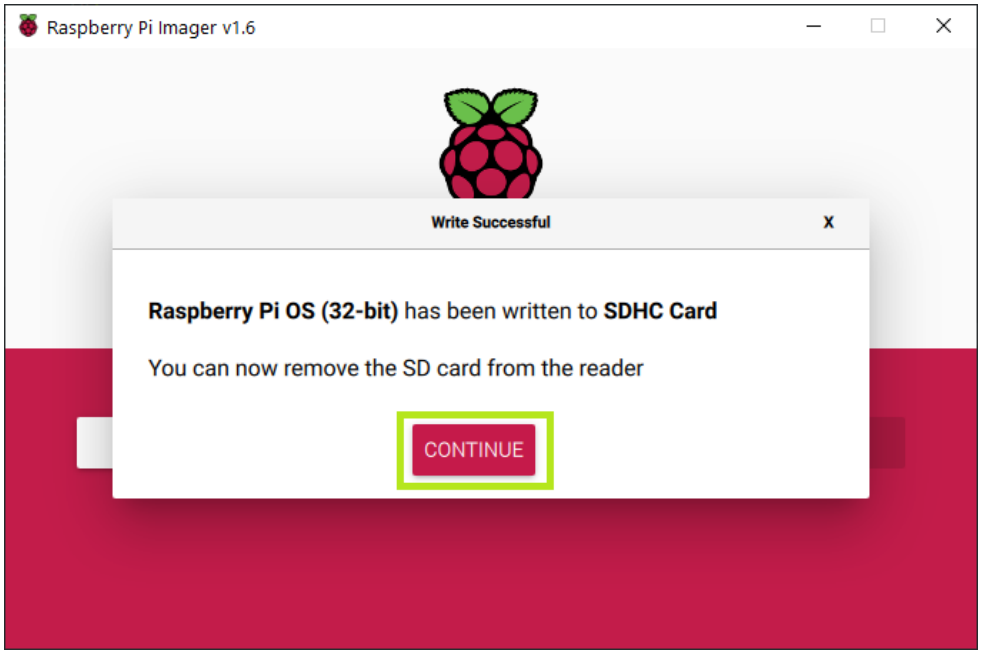
   Click Yes to overwrite the SD Card.

   The Yes button is boxed in **green** in the image below.



10. Wait for the OS write process to complete.

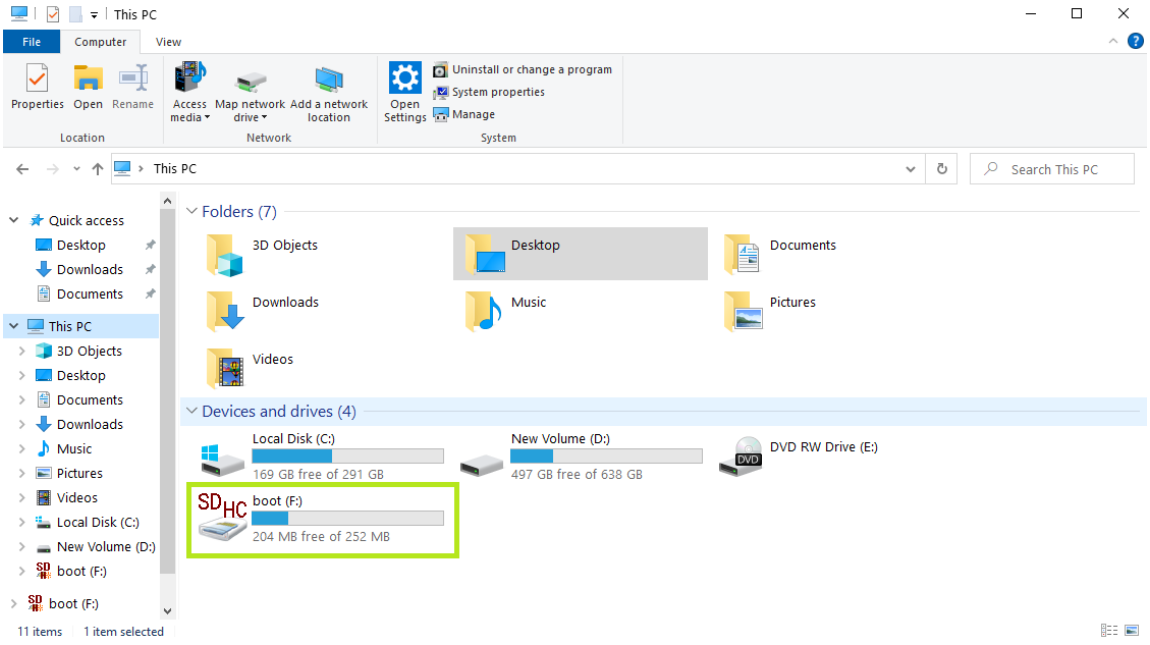
    Upon completion, click the Continue button boxed in **green** in the image below.



11. Eject the SD Card and re-insert the SD Card into the PC again.

    Open the File Explorer and go to This PC.

    A boot drive should appear after re-inserting the SD Card.



Step 2: Insert the Micro SD card into the Raspberry Pi

The Payload uses a Raspberry Pi 3B+, which is a credit card sized computer.

The Micro SD card comes pre-loaded with the necessary setup to be done to run the Payload and should be already inserted in the Micro SD card slot of the Raspberry Pi 3B+.

The Micro SD card slot is underneath the Raspberry Pi 3B+ shown in the screenshot below.

The Micro SD card slot is boxed in **red** in the screenshot below.

Double check that the Micro SD card is fully inserted into the Micro SD card slot by gently pushing the Micro SD card inwards.

Step 3: Power up the Raspberry Pi

Power up the Raspberry Pi using a microUSB cable connected to either (1) a 5V 2A USB power source (eg. mobile phone charger) or (2) the Raspberry Pi power supply.

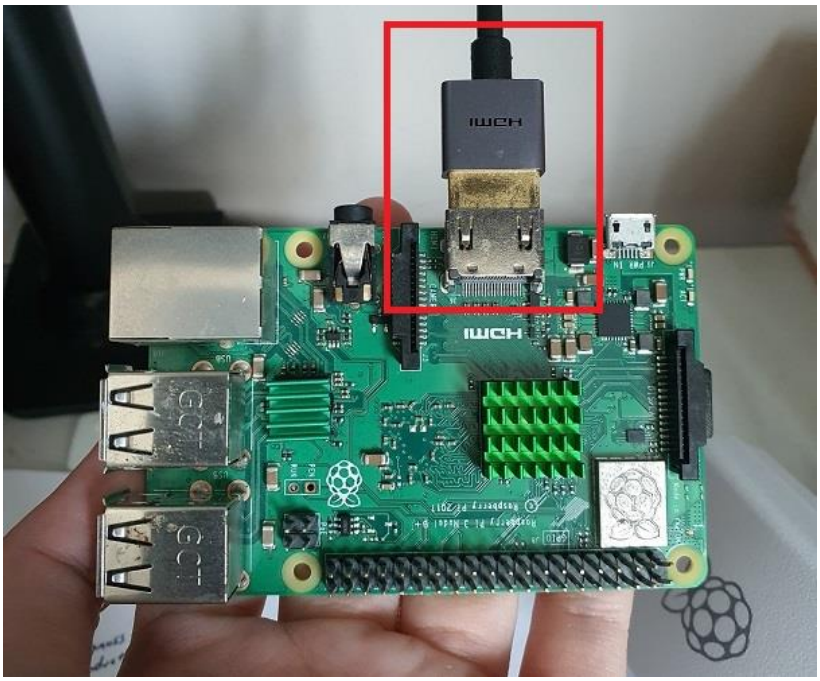
Step 4: Viewing the Display and controlling the Raspberry Pi

As the Raspberry Pi is a mini computer, there are several ways to access the Raspberry Pi and view the screens like a regular PC.

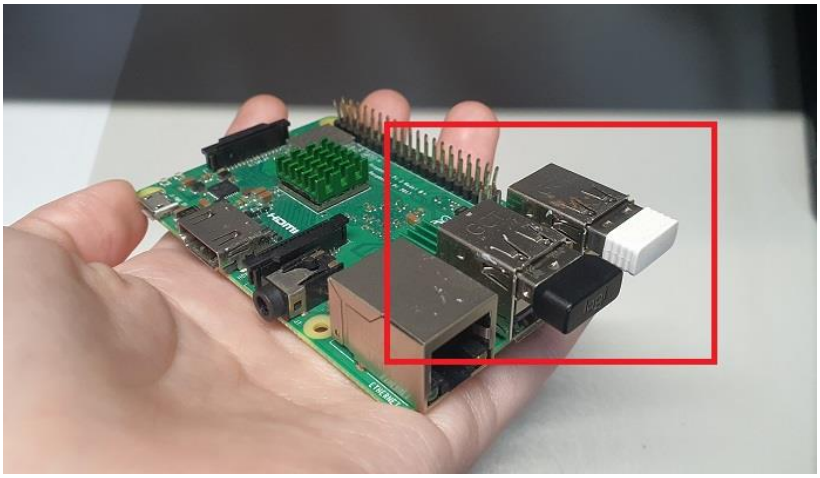
One way is to directly view the screen by connecting a display monitor to the Raspberry Pi and controlling it with a USB mouse and keyboard.

Plug in a HDMI cable to the Raspberry Pi and connect the HDMI cable to a Monitor.

The HDMI port is boxed in **red** in the screenshot below.

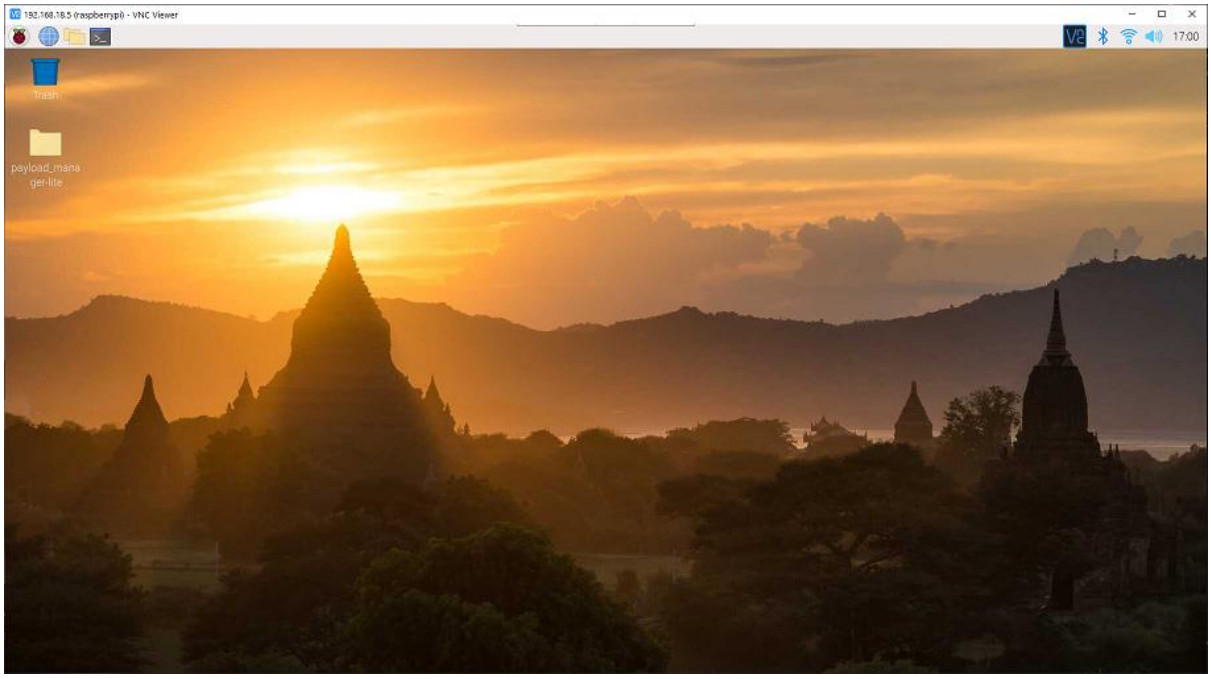


Connect the USB keyboard and USB mouse to the Raspberry Pi's USB ports.



Switch to the HDMI source to view the Raspberry Pi GUI.

Upon successful viewing of the GUI, the following screen will show:



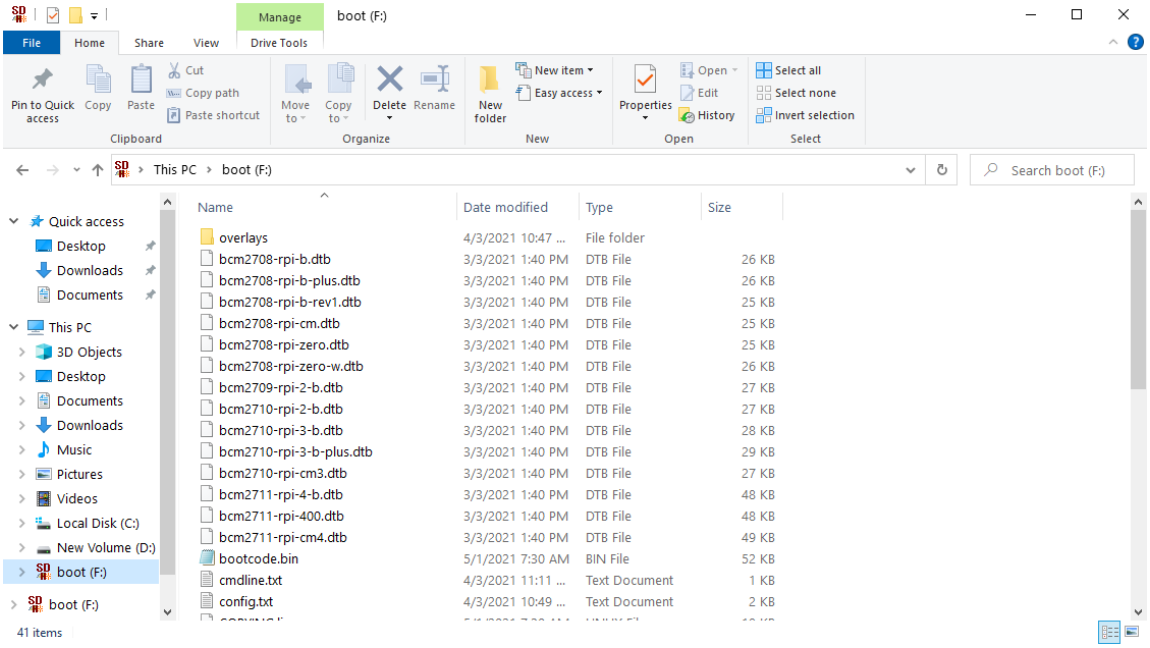
⚠ **Note: You might be required to configure the GUI upon first start up. There is an appendix section at the end of this document which shows you how to configure it.**

Step 5: Copy Custom Setup scripts to the SD Card

1. Power off the Raspberry Pi, remove the SD Card from the Raspberry Pi and re-insert the SD Card into the PC again. We are now going to copy a few scripts that will be used onto the SD card.

2. Click on the boot drive in File Explorer.

   ⚠ **Do not open or make changes to any files in this drive, unless you are 100% sure.**

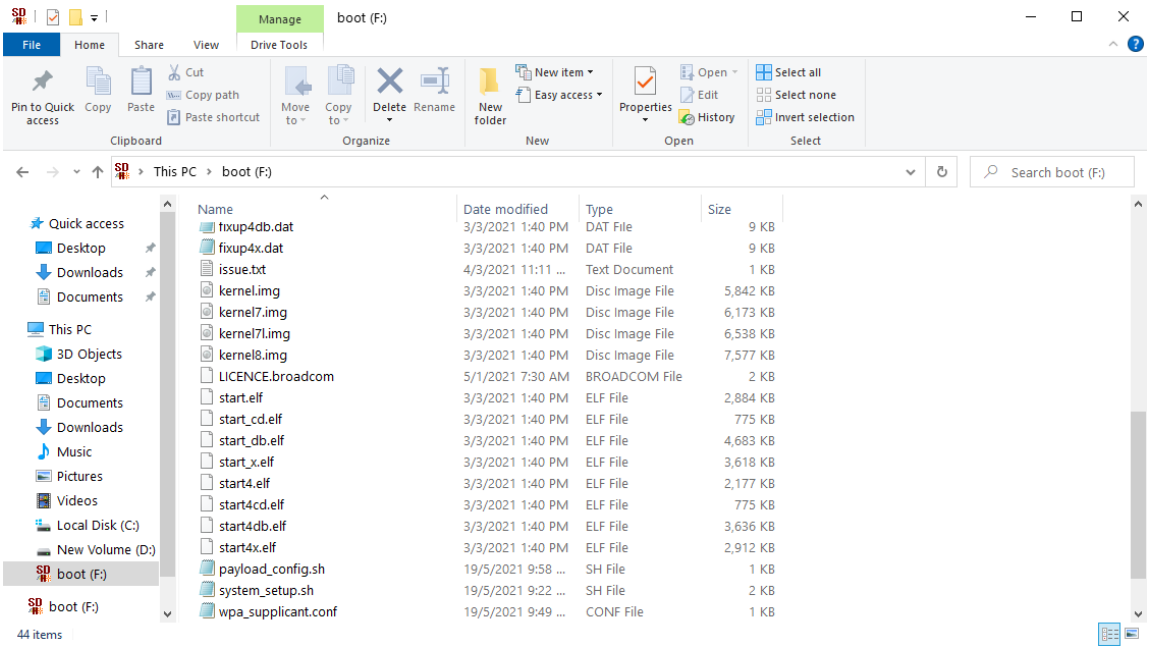


3. Download and copy the config scripts into the boot drive.

   ⚠ **Do not edit any part of the files, except for those steps in the instructions.**

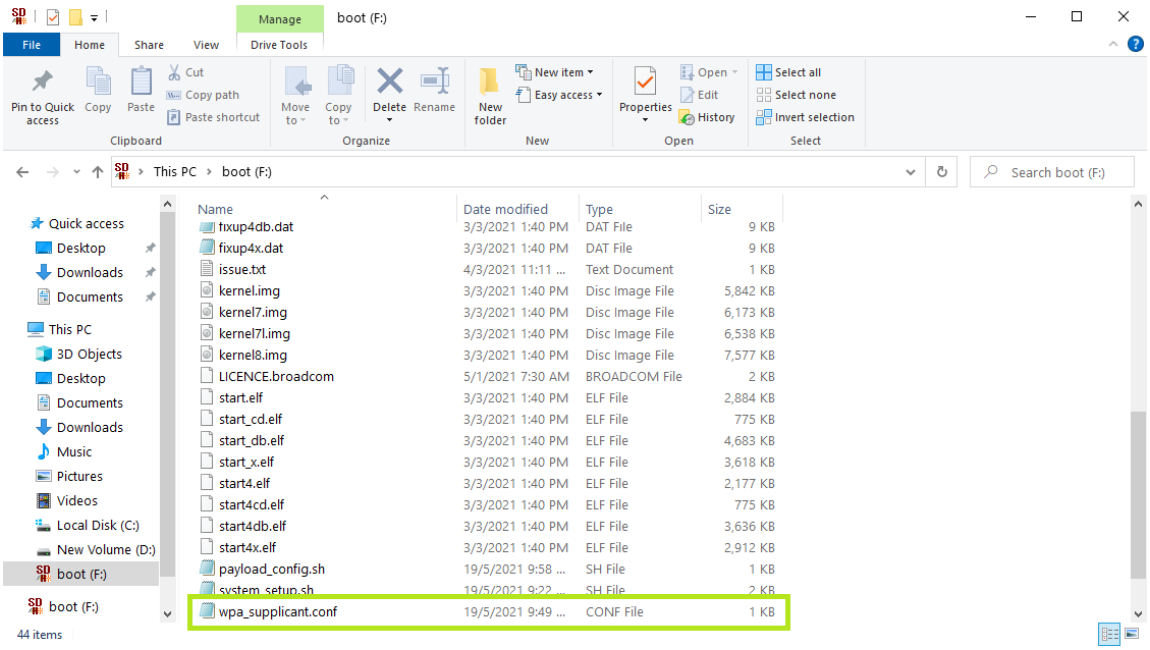
4. The config scripts can be downloaded from here:
    - payload_config.sh
    - system_setup.sh
    - wpa_supplicant.conf

Once the copying is complete, the 3 files should appear like in the image below.



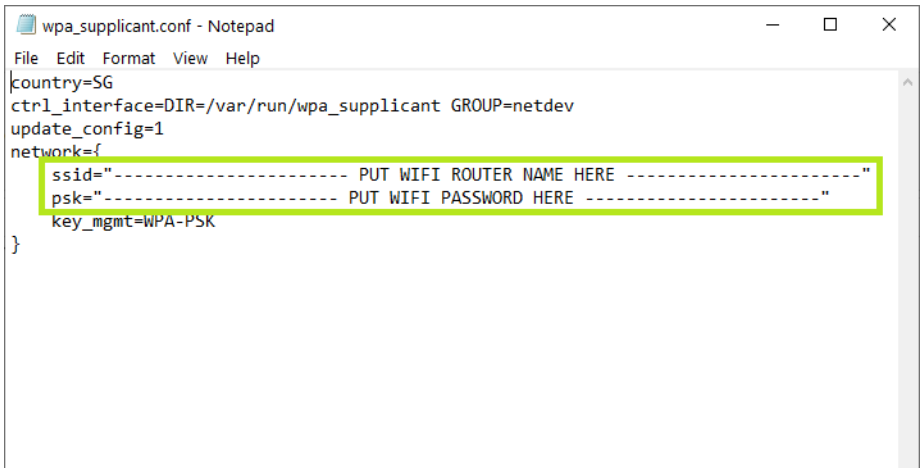
Step 6: Configure WiFi credentials to the Raspberry Pi OS

1. Locate the wpa_supplicant.conf file in the boot drive and open it using Notepad.



2. Fill in the template with the WiFi Router name and the Password.

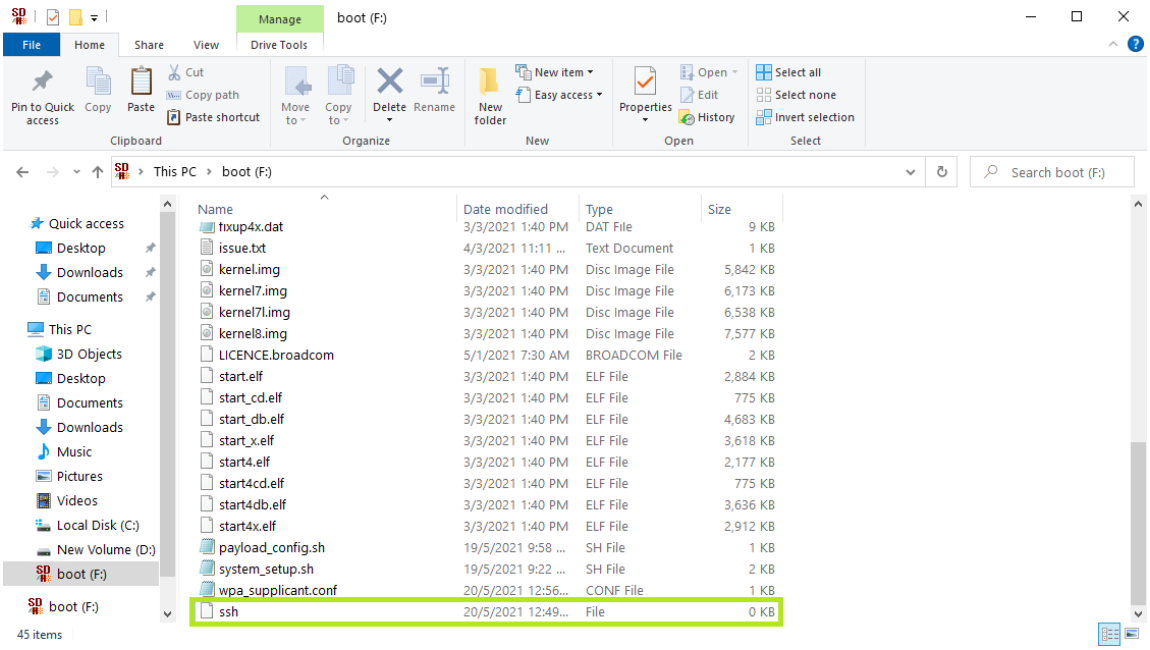
   Save the changes in the file.



⚠ **Note: We recommend you to turn on and use your mobile hotspot as it will be much easier to access the Raspberry Pi in this manner. Do take caution not to use the Raspberry Pi to download large files from the internet (or watch YouTube) as it may result in high data charges.**

Step 7: Enable SSH in the Raspberry Pi OS

1. Download an empty ssh file from the link here.
2. Copy the file into the boot drive.



Step 8: Boot up Raspberry Pi

Re-insert the SD card onto the Raspberry Pi and power up the Raspberry Pi.

Note: There are 2 paths to choose from.

(1) Follow step 9A if you have a monitor connected to the Raspberry Pi.

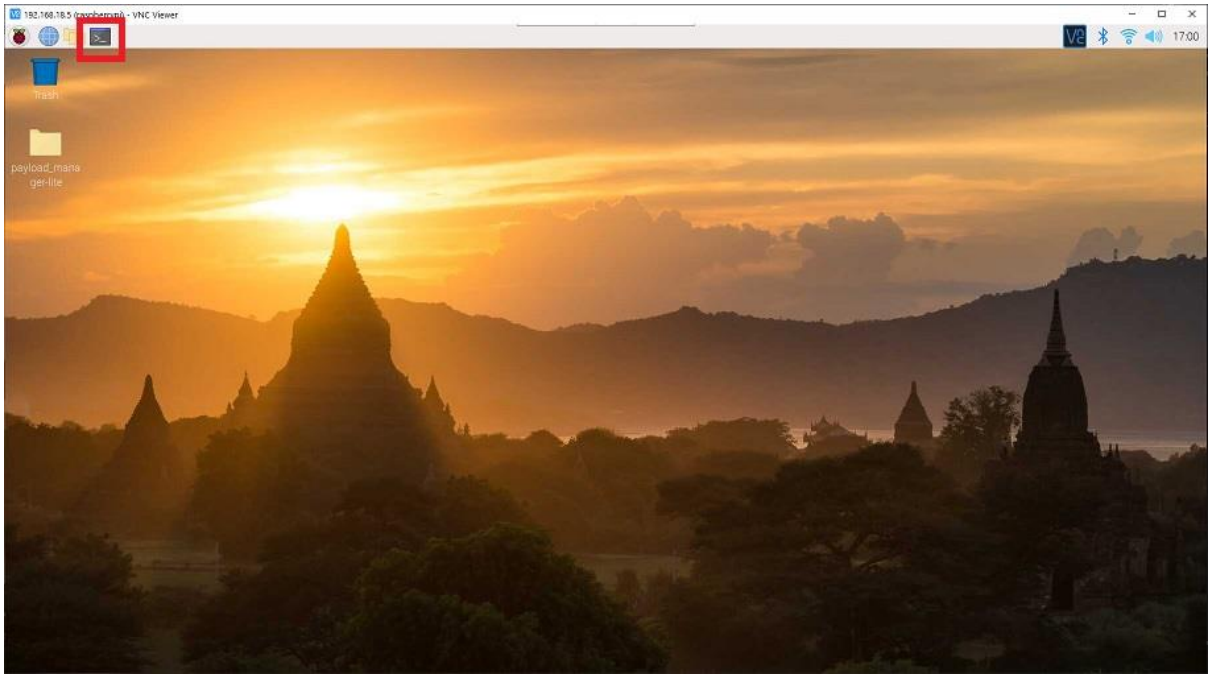
⚠ **(2) Follow step 9B if you do not have a monitor connected to the Raspbery Pi.**

The commands to be run in step 10 are similar no matter which path was chosen.

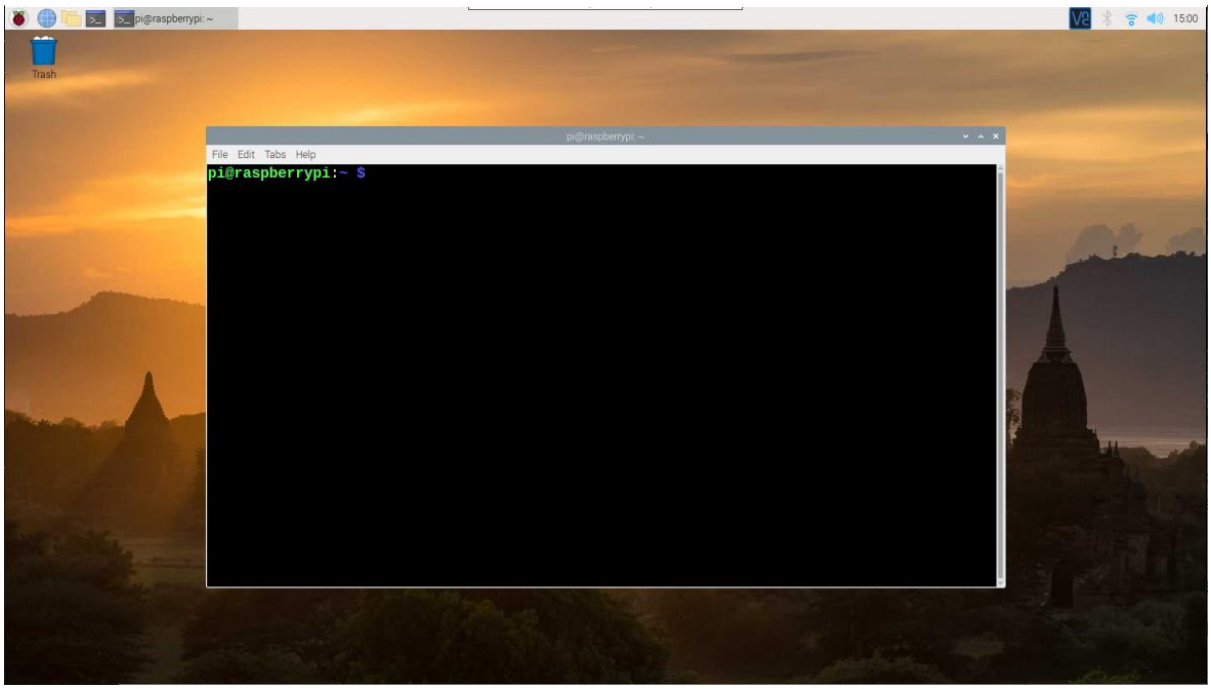
Step 9A: Open up the Terminal window

Click on the Terminal icon at the taskbar.

The Terminal icon is boxed in **red** in the screenshot below.



The Terminal window will open up, like in the screenshot below.



Step 9B: SSH into Raspberry Pi

1. Ensure that PuTTY is installed on the PC.

   You may download PuTTY from this website here

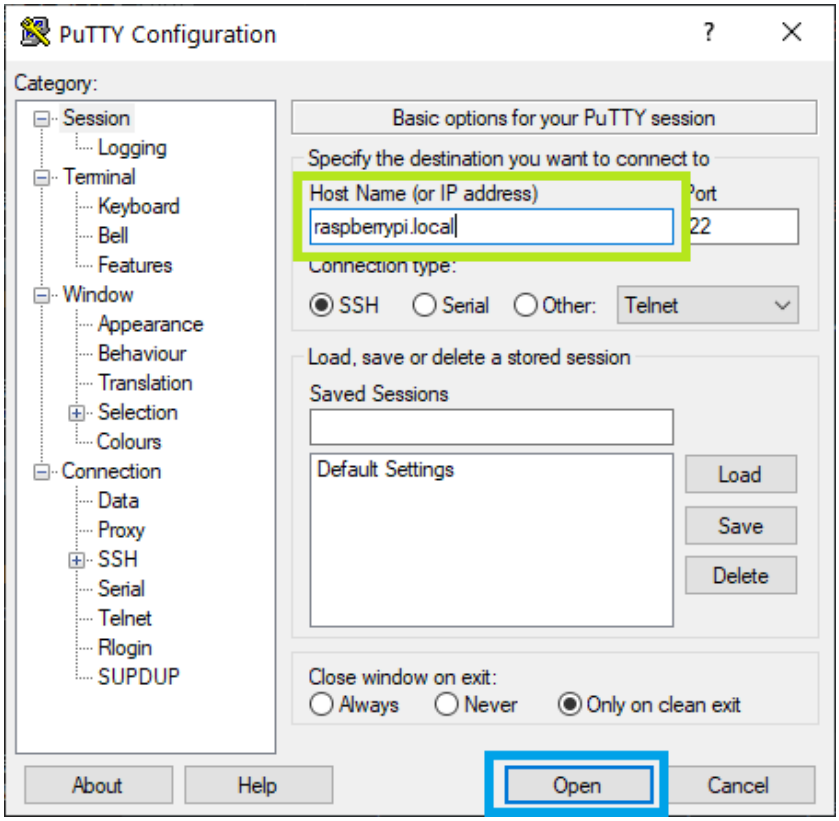
   Website: https://www.chiark.greenend.org.uk/~sgtatham/putty/latest.html/

2. Open up PuTTY and SSH into PuTTY.

   To SSH into PuTTY, enter raspberrypi.local into the Host Name (or IP address) box boxed in **green** in the image below.

   Ensure that the Port entered is 22 (by default).

   Click Open, which is boxed in **blue** in the image.

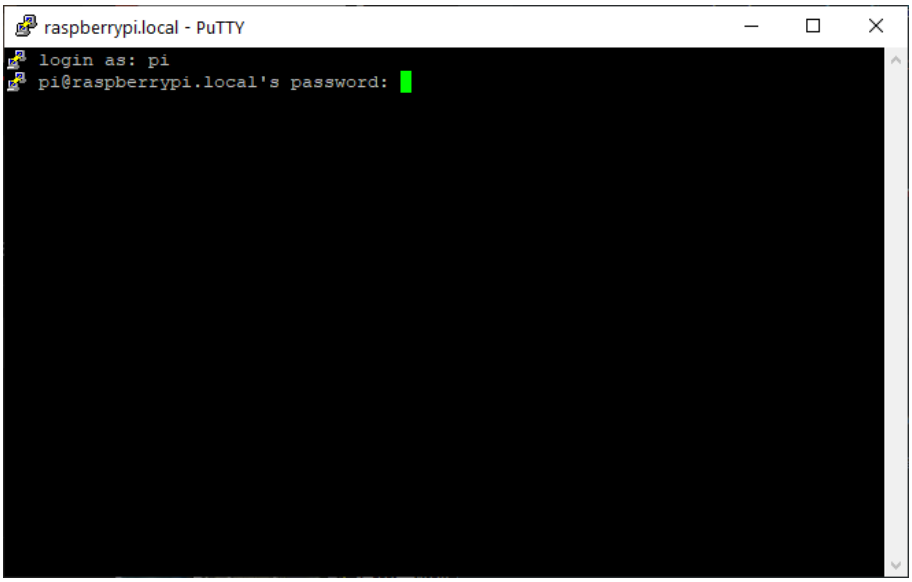


3. Login to the Raspberry Pi when prompted.

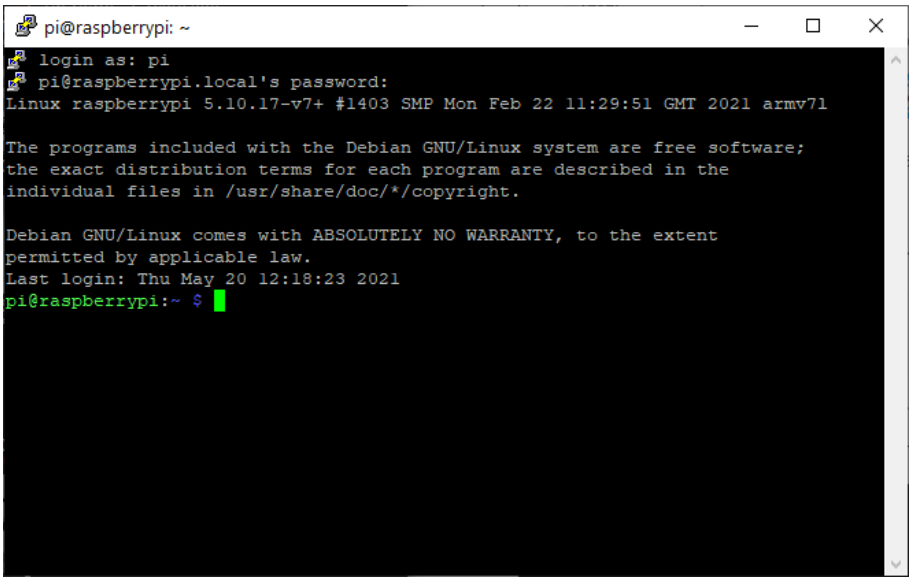
   The default credentials for Raspberry Pi login are here:

   - username: pi
   - password: raspberry

   After entering the username and password individually (and sequentially), press Enter to confirm.



If the login is successful, the screen below will appear.



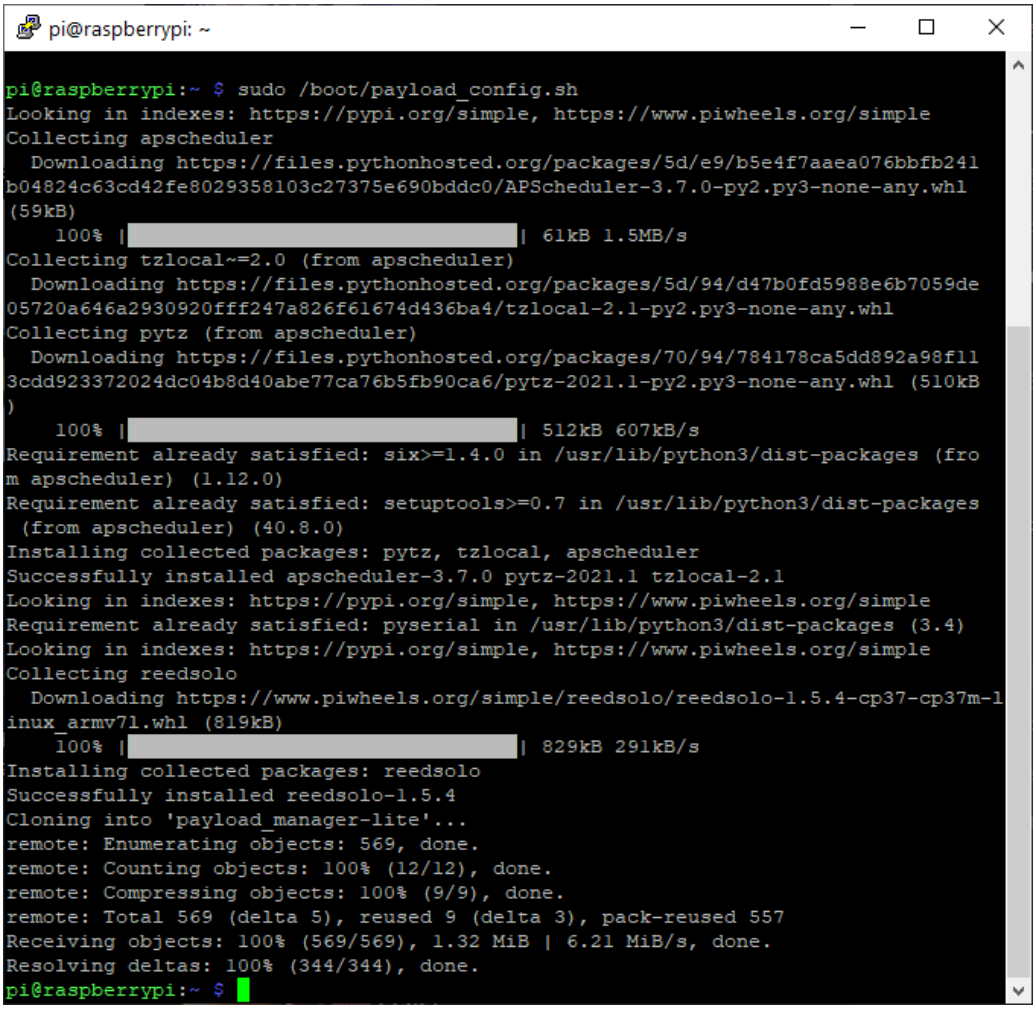
Step 10: Run Custom Setup scripts in Raspberry Pi

1. Run the payload_config.sh script that is saved in the boot drive to install the libraries and Payload Manager code.

   To do so, type the following command into the PuTTY terminal and press Enter:

   sudo /boot/payload_config.sh

   The payload_config.sh script will run and wait till its completion.

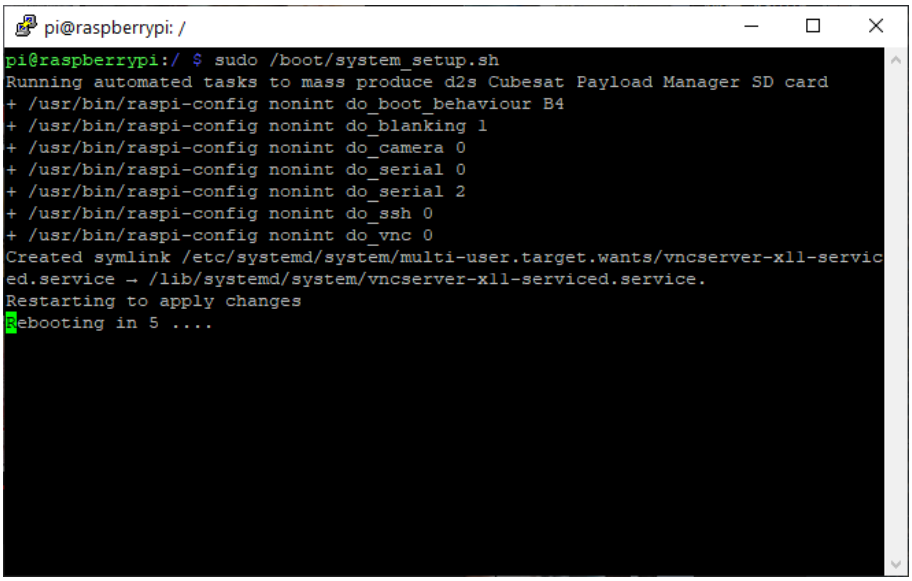


2. Run the system_setup.sh script that is saved in the boot drive to setup the Raspberry Pi.

   To do so, type the following command into the PuTTY terminal and press Enter.

   sudo /boot/system_setup.sh

   The system_setup.sh script will run and wait till its completion.



Upon its completion, the Raspberry Pi will reboot and the PuTTY terminal connection will be disconnected.

Close the PuTTY terminal.

Step 11: Connect and Test Payload Camera

We will now start to connect the camera and test that it is working. This step is applicable only if a monitor is connected to the Raspberry Pi.

1. Connect the provided Raspberry Pi camera according to the guide listed in this website: https://projects.raspberrypi.org/en/projects/getting-started-with-picamera/

2. Take a group selfie by typing the following command into the terminal and press Enter:

   ```
   raspistill -o Desktop/image.jpg
   ```

   The picture should appear on the desktop when run correctly. If unable to do so, please inform the course instructors.

3. The link above provides more information about how the Raspberry Pi camera can be used together with the Raspberry Pi with Python (a scripting language) and you may reference it should you be interested in learning more.

⚠ **We are done with the set up of the payload computer and have tested the payload camera. The next step of this guide is to set up the wireless communication transceivers.**

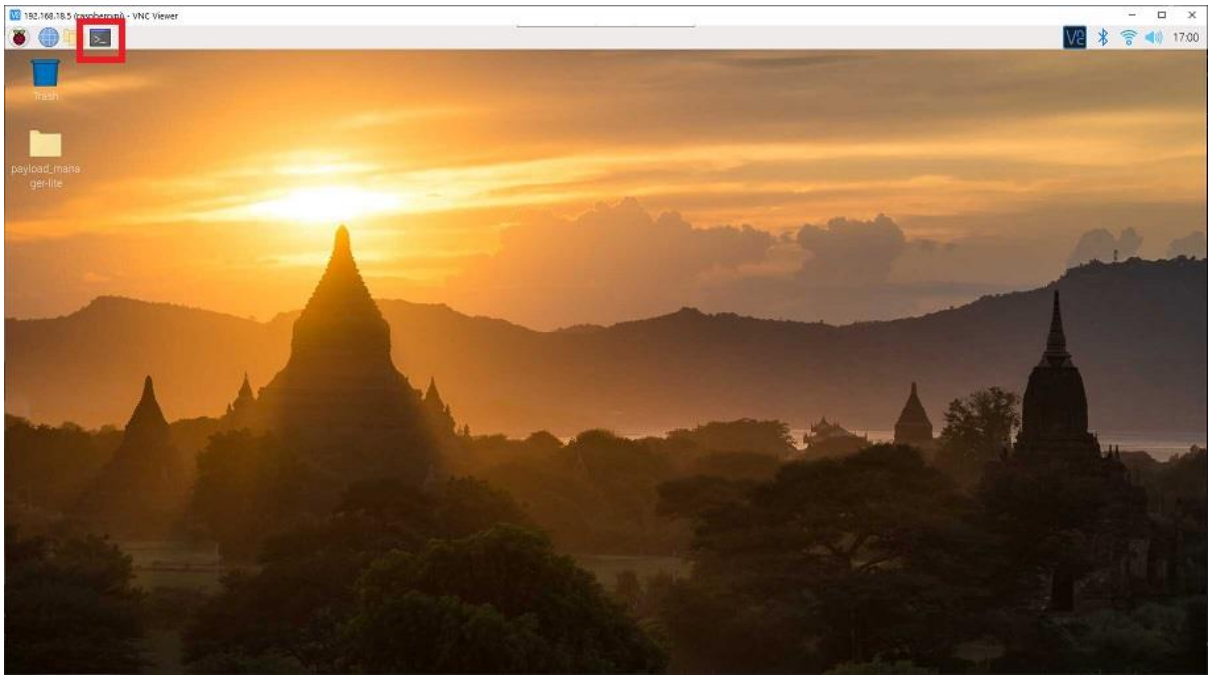
Additional Notes for Payload Computer

If all the steps above were done correctly, the payload program would be able to run. This can be tested using the steps listed below. However, without input from the ground station application, there will not be any commands coming in.

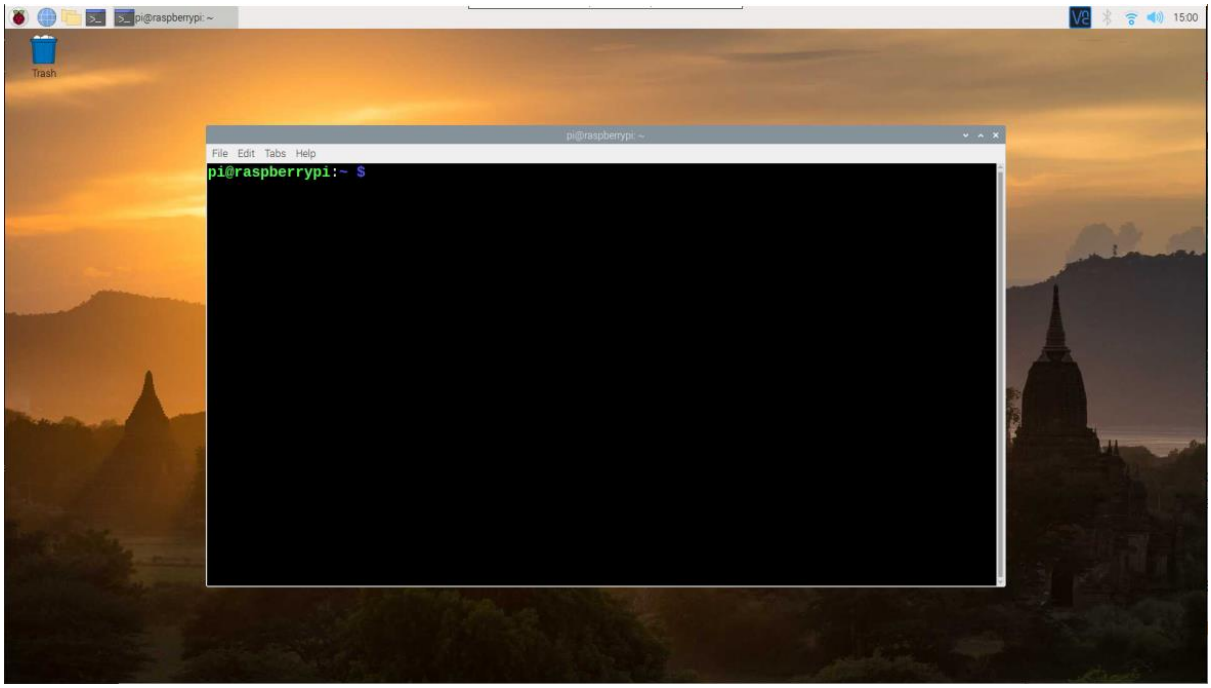
Step 1: Open up the Terminal window

Click on the Terminal icon at the taskbar.

The Terminal icon is boxed in **red** in the screenshot below.



The Terminal window will open up, like in the screenshot below.

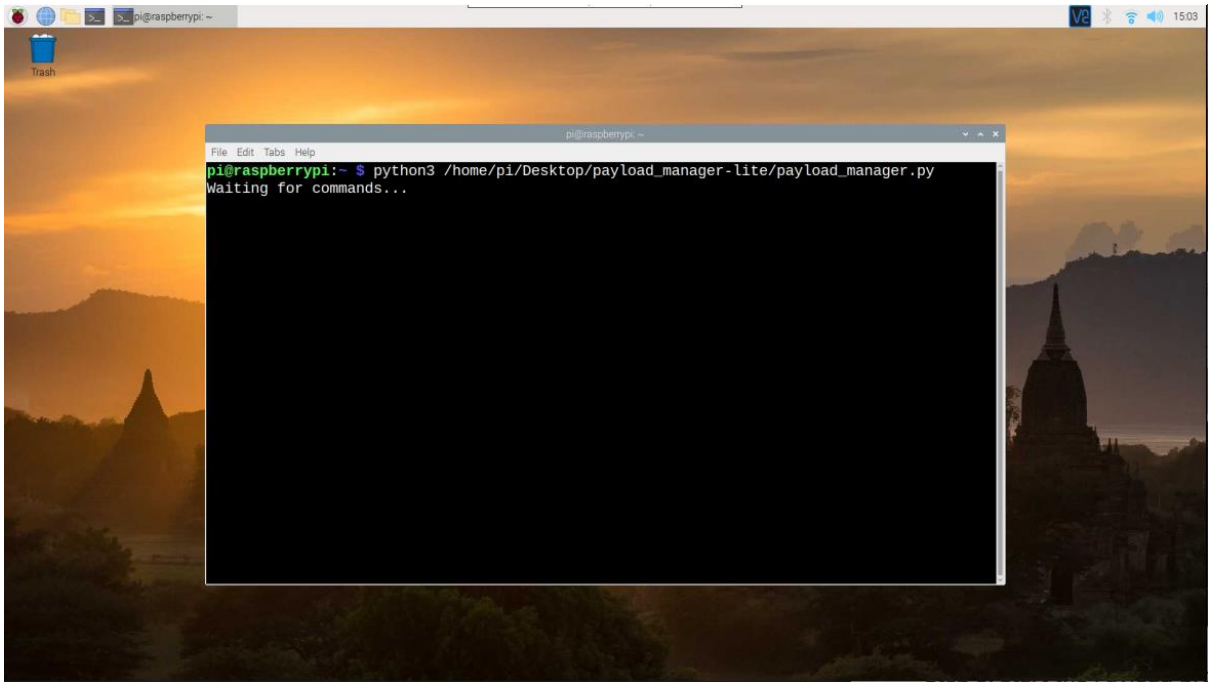


Step 2: Start the Payload program

Type the following command exactly into the Terminal window.

```
python3 /home/pi/Desktop/payload_manager-lite/payload_manager.py
```

Once the command has run successfully, the Terminal window will display the following output to wait for new Commands from the Cubesat.



Wireless Transceiver Configuration

Items Required

Here is a list of items required to configure the transceivers per Cubesat.

Items	Remarks
HC-12 Transceiver	Need 2 per Cubesat
USB-UART bridge	Need 2 per Cubesat
Jumper wires	To connect the transceiver to USB-UART bridge
Laptop	Requires Python3 installed
Breadboard	Suggested nice-to-have item

Setup and operations best done on a PC that runs on Windows 10.

For reference:

Datasheet for HC-12

Background Idea

The HC-12 transceiver is a transceiver that operates at a radio frequency of 433.4-473.0 MHz with a step of 400 KHz, amounting to 100 channels in total.

The transceiver configurations are required to allow a pair of transceivers to be able to reach each other at the same frequency channel.

Balancing and allocation of channels are important to fight radio frequency interference between multiple transceivers, which is especially pertinent for the Payload transceiver.

A script is written for easy configuration of the transceivers to their desired radio frequency channels.

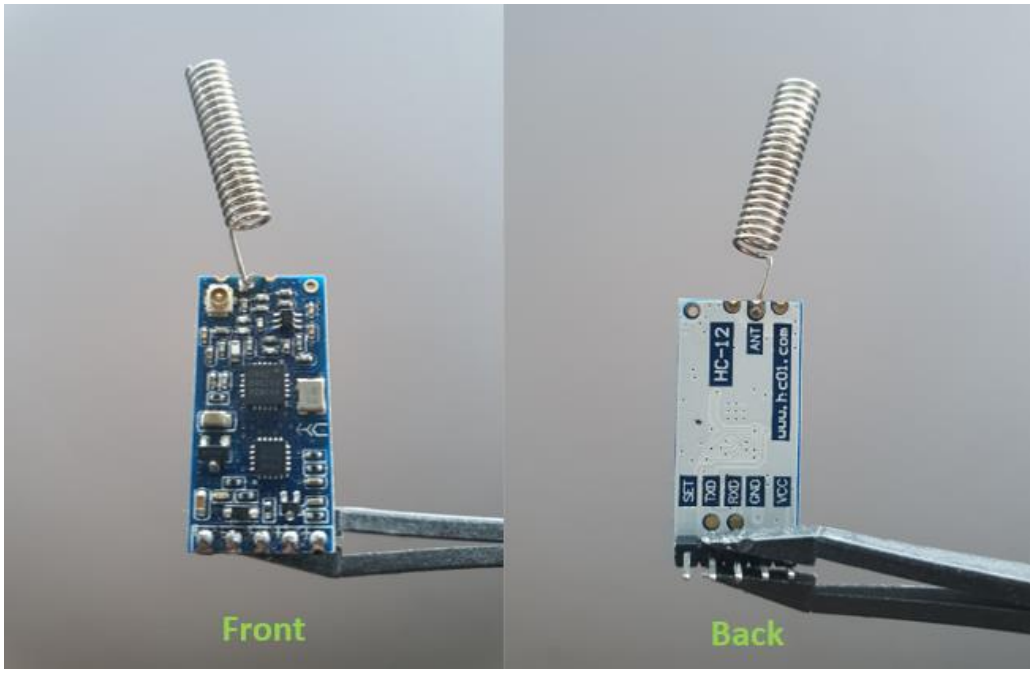
TIP!

As a class, you might want to decide on fixed transmission channels for your groups. This will prevent interference coming from another team's transceivers.

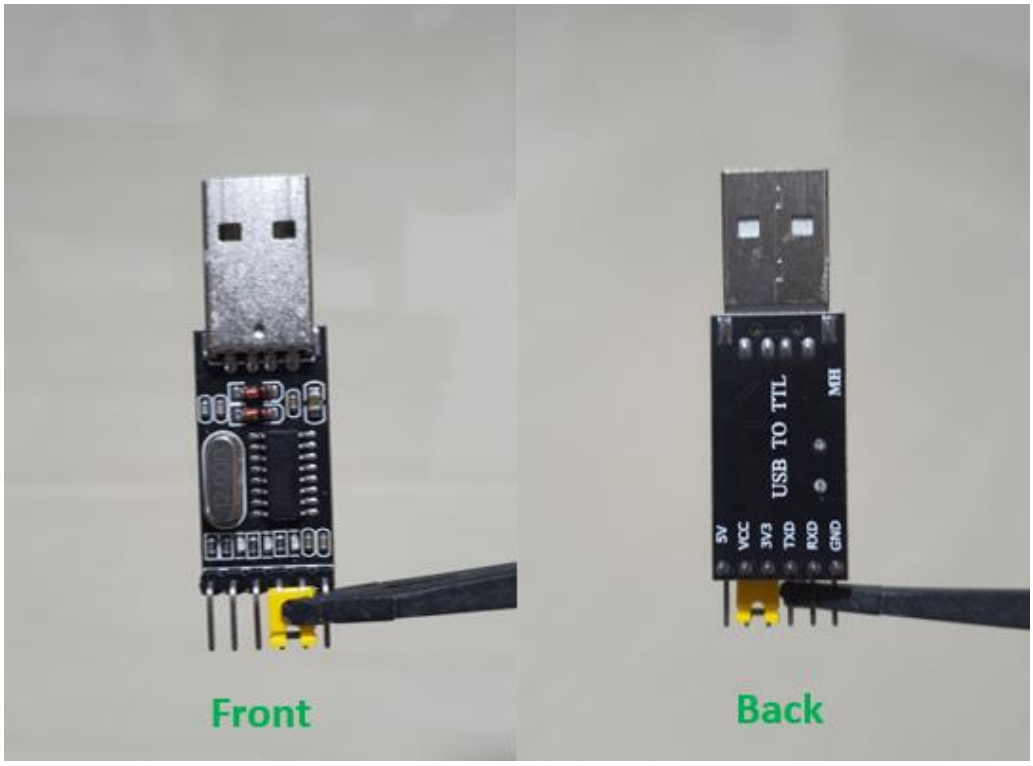
Getting Started

To get started, the transceivers that are to be configured need to be connected to the USB-UART bridge.

This is how the transceiver looks like:



This is how a USB-UART bridge looks like:

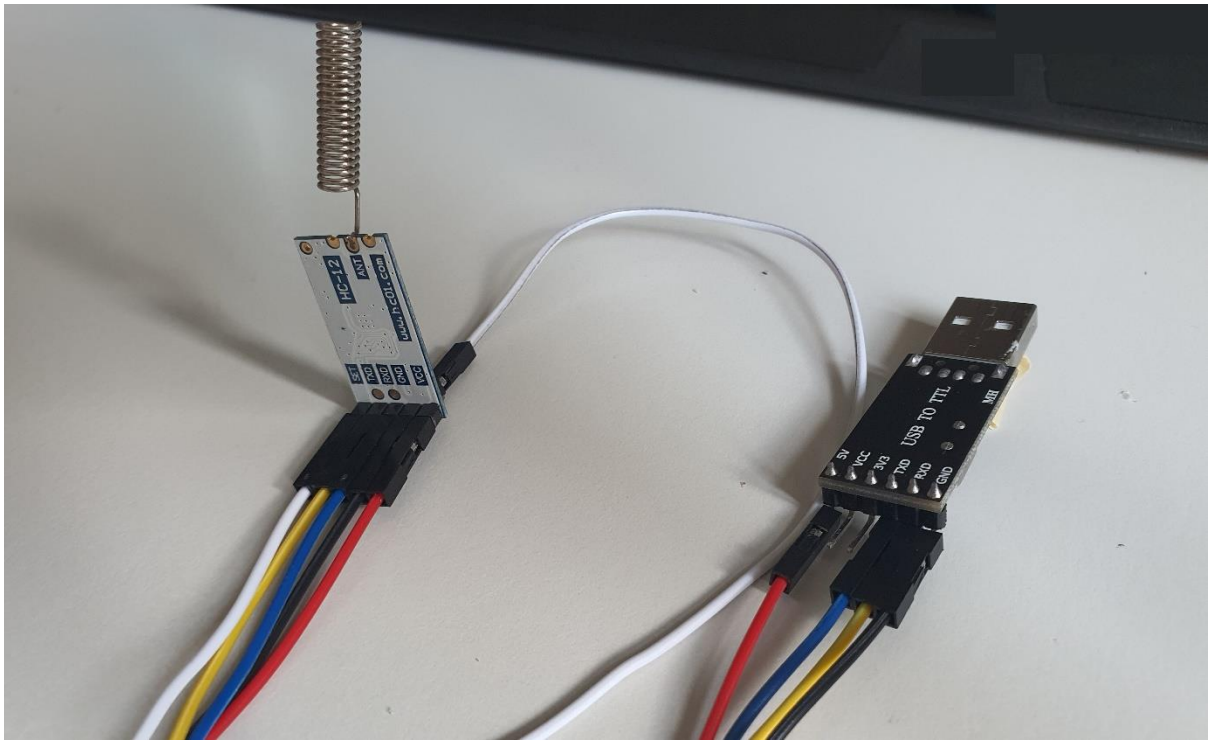


Make the following connections between the transceiver and USB-UART bridge using jumper wires and a breadboard.

USB-UART bridge	Transceiver
5V	Vcc
GND	GND
TX	RX
RX	TX
GND	SET

Note: The SET pin of the transceiver needs to be connected to ground to enter AT mode for configuration.

An example of the transceiver connected to the USB-UART bridge is shown below:



⚠ **Note: You may use anything electrically conductive to make the connection between GND of the USB-UART bridge to the SET pin of the Transceiver. We heard that this may come across as very sus, so we recommend to use a jumper cable (pictured above) to make this connection. Do get a friend to help hold down the modules if you are finding it difficult to do it on your own.**

Configuration

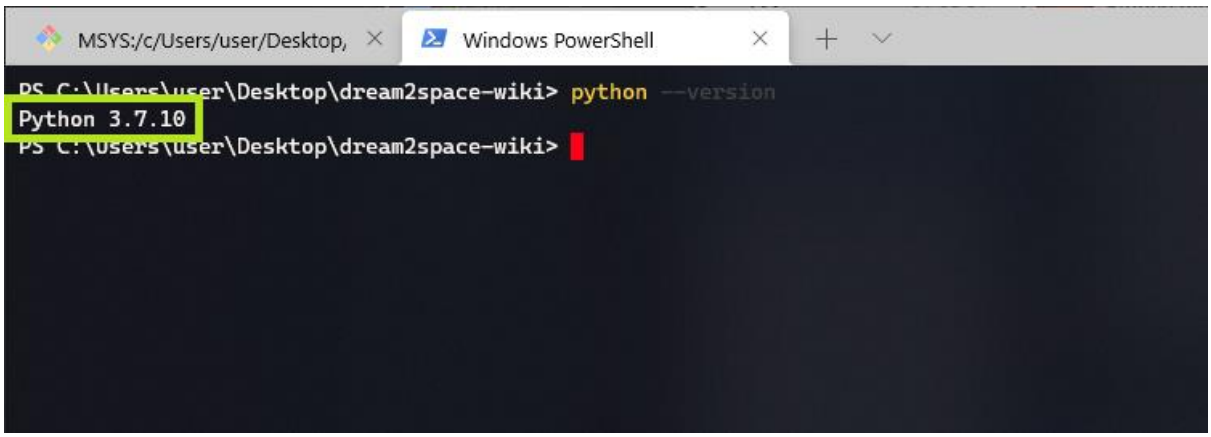
Step 1: Setup necessary libraries

Open Windows Powershell terminal.

Ensure that Python 3 installed on the PC by typing the following command:

```
python --version
```

If Python 3 was installed, the following message will be shown.



Install the following libraries by entering the following command:

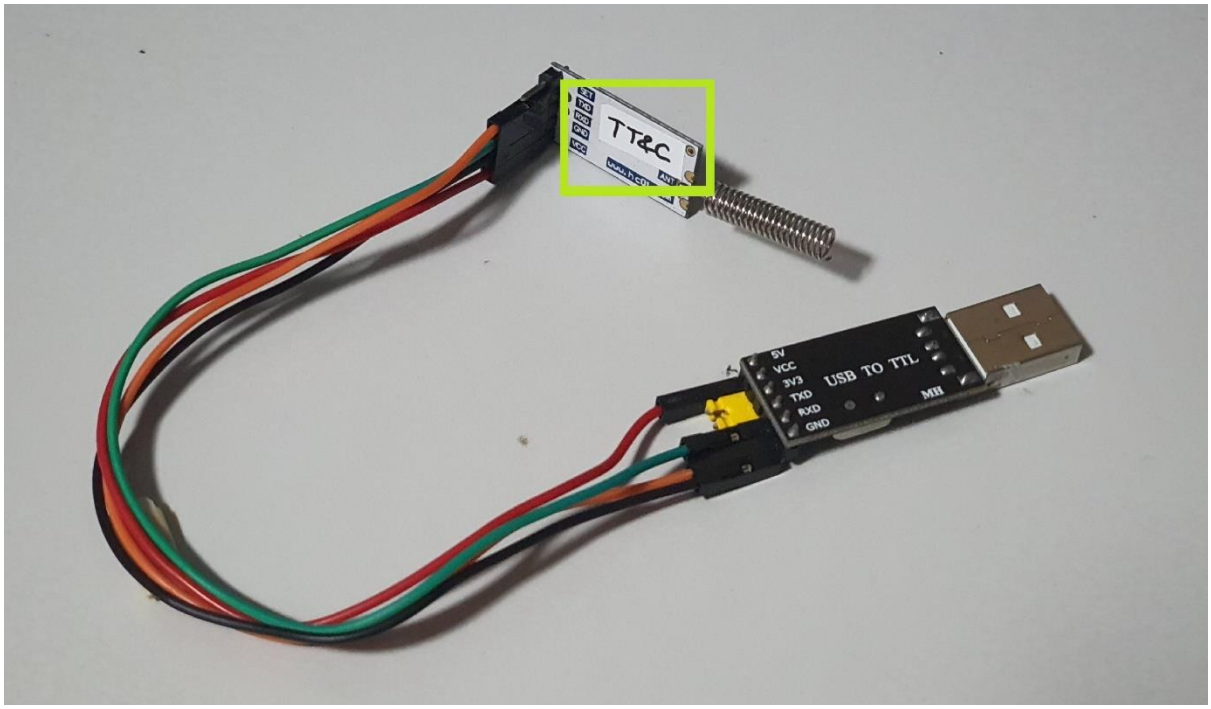
```
pip install pyserial
```

Download the transceiver setup program here

Step 2: Label TT&C transceivers

It is important to label the pair of transceivers that will be used for the TT&C before proceeding with the configuration.

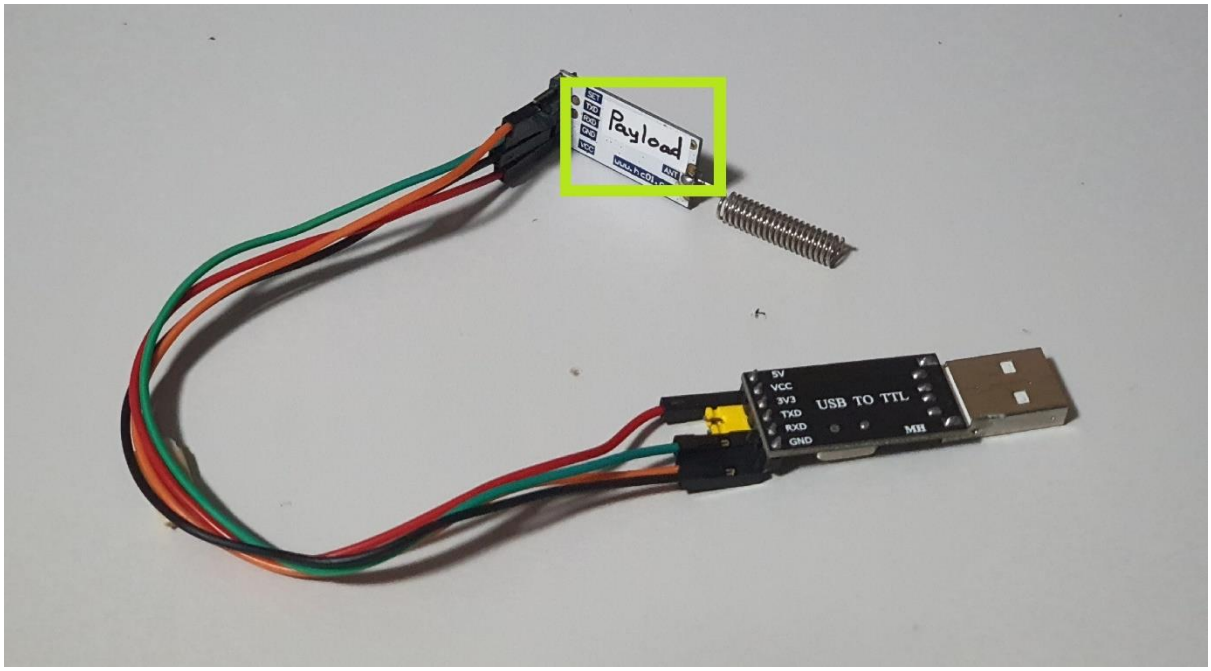
An example of the labelling is done as shown in the screenshot below.



Step 3: Label Payload transceiver

Similarly, label the pair of transceivers that will be used for the Payload before proceeding with the configuration.

An example of the labelling is done as shown in the screenshot below.

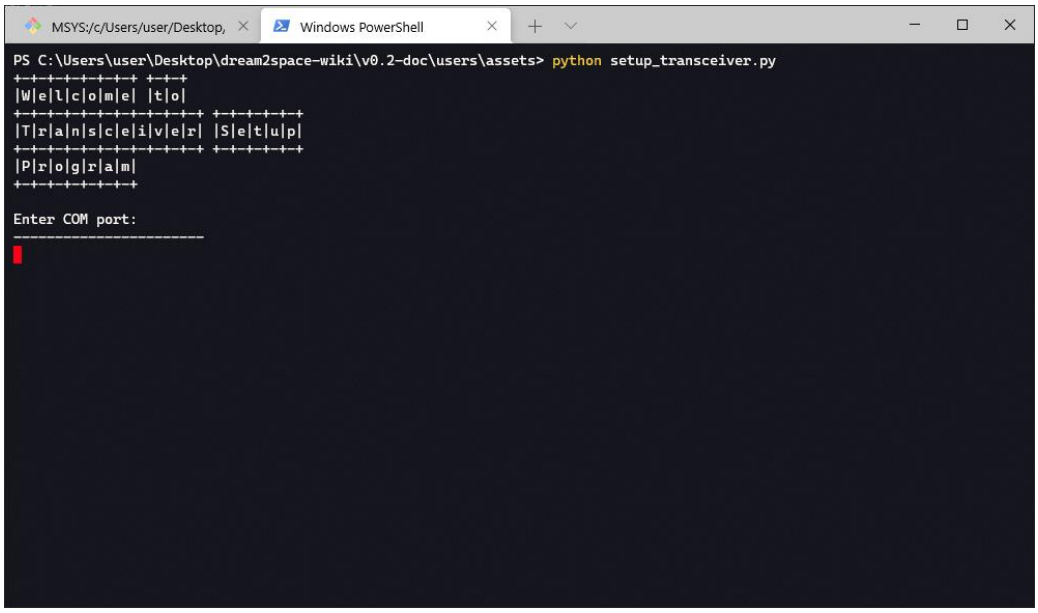


Step 4: Configure TT&C transceiver

To configure the transceiver, run the transceiver setup program by entering the command:

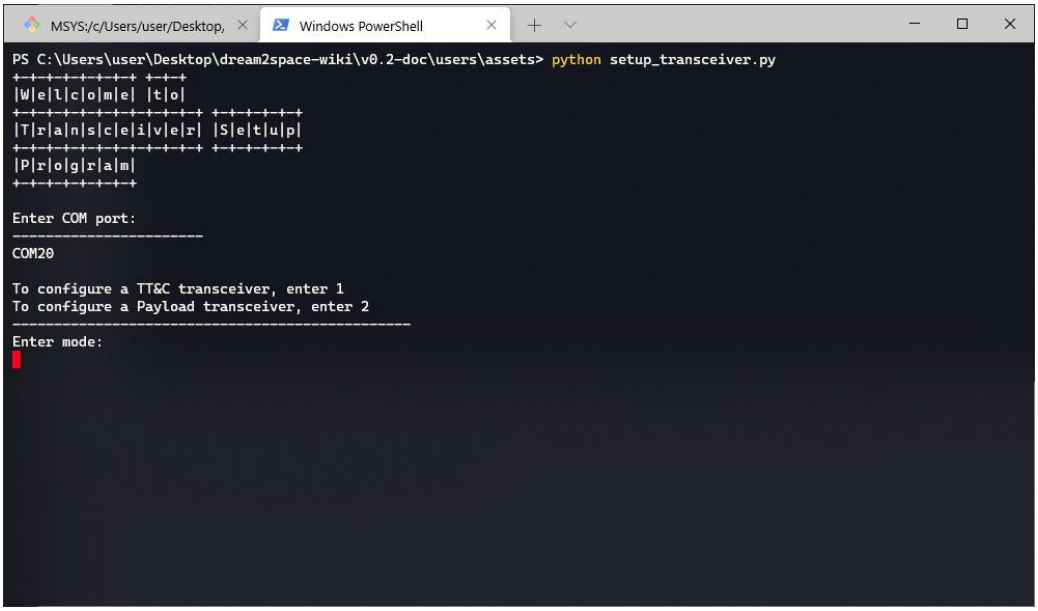
```
python3 setup_transceiver.py
```

The program will start running and the Powershell terminal will show a Welcome banner as shown in the screenshot below.



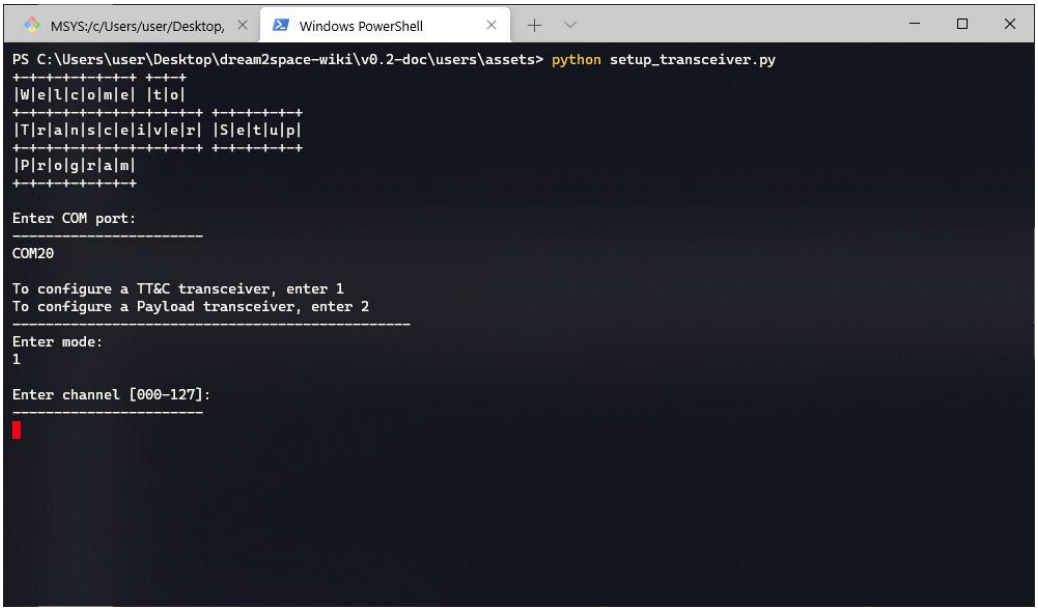
Enter the COM port as instructed and adhere to the format COMXX, where XX is the port number.

An example and the output are shown in the screenshot below.



Next, enter 1 to configure a TT&C transceiver.

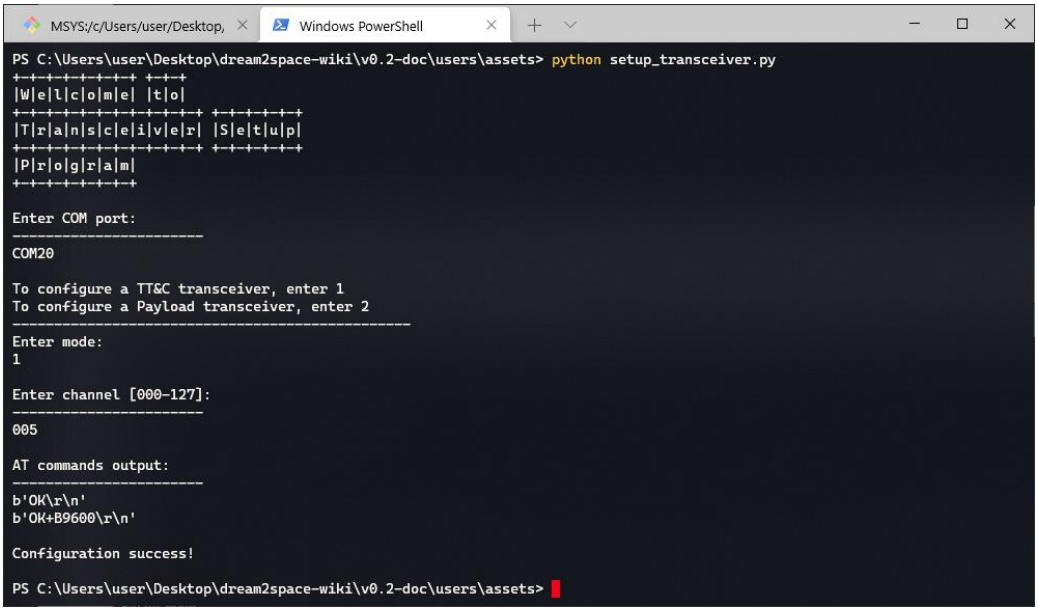
An example and the output is shown in the screenshot below.



Enter the channel that the TT&C transceivers will communicate in and adhere to the format as instructed by the program.

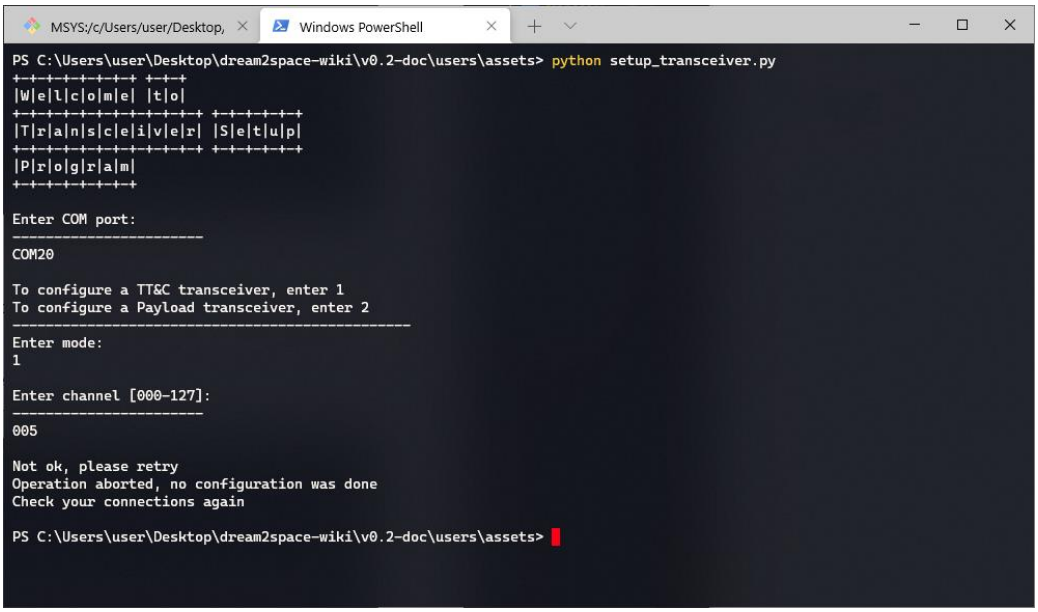
The program will attempt to configure the transceiver and if it is successful, a success message will be

An example and the output is shown in the screenshot below.



Once successful, repeat the step for the other transceiver of the transceiver pair.

If the program is unable to communicate with the transceiver, the error message will be shown as follows.



Here are some tips to troubleshoot before repeating the step for the current transceiver:

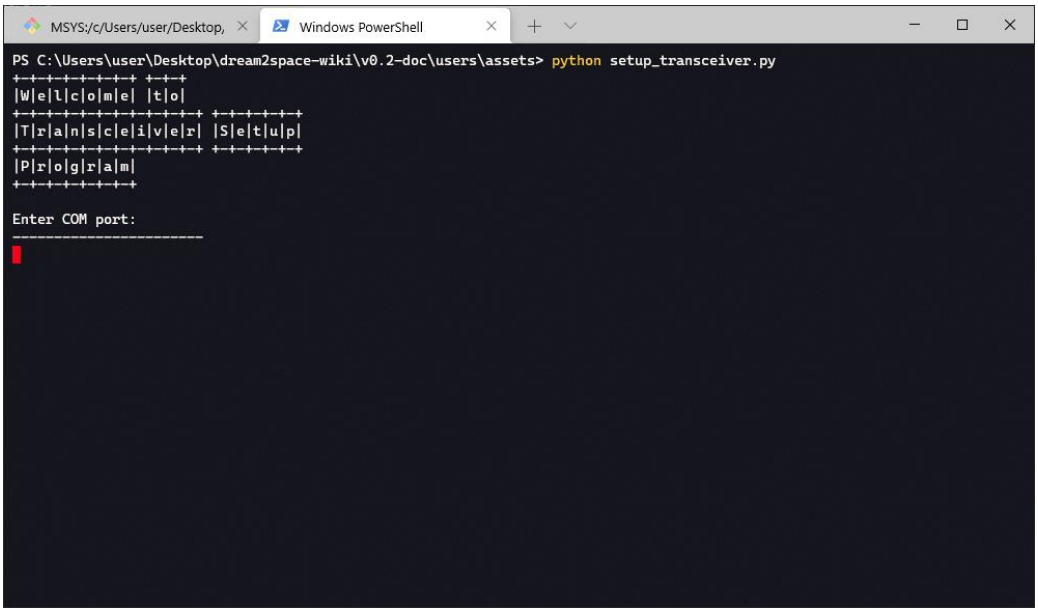
1. Check the connection of the SET pin - ensure it is connected to GND.
2. Ensure that the USB-UART bridge is inserted into the PC.
3. Double check the connections between the USB-UART bridge and transceiver for any loose connections.

Step 5: Configure Payload transceiver

To configure the transceiver, run the transceiver setup program by entering the command:

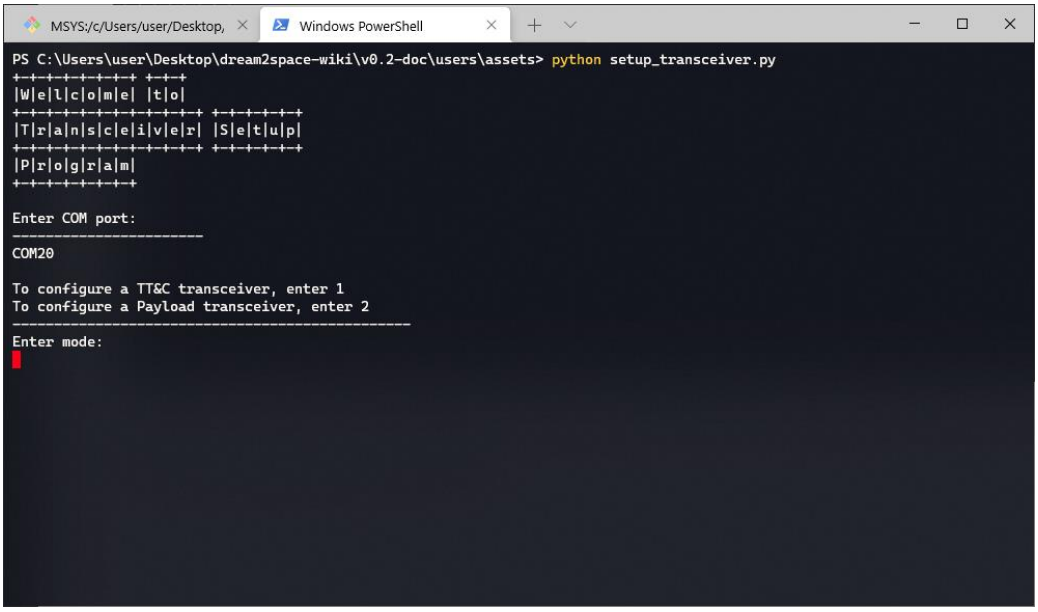
```
python3 setup_transceiver.py
```

The program will start running and the Powershell terminal will show a Welcome banner as shown in the screenshot below.



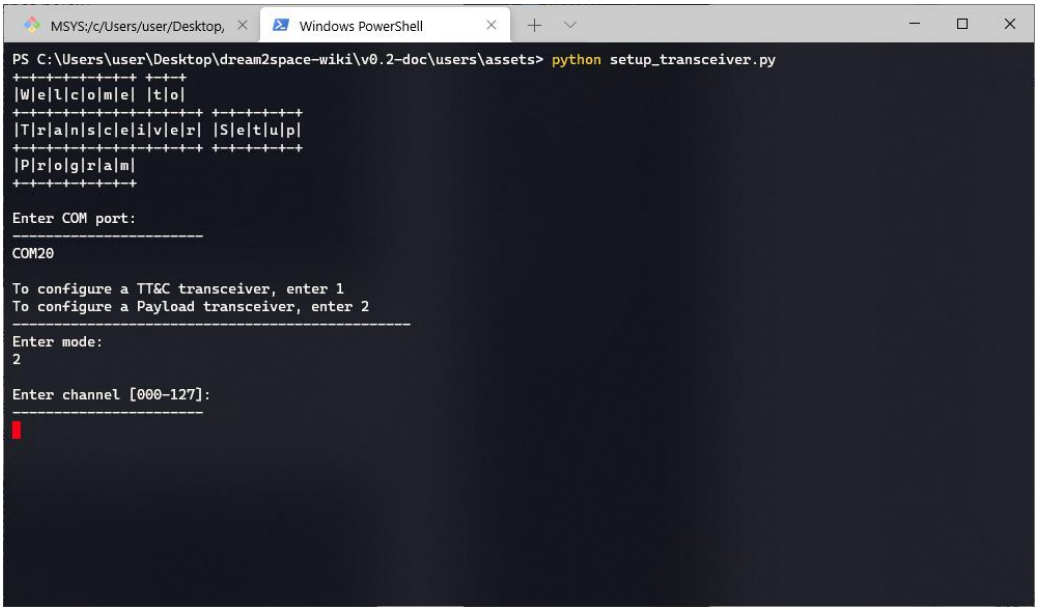
Enter the COM port as instructed and adhere to the format COMXX, where XX is the port number.

An example and the output is shown in the screenshot below.



Next, enter 2 to configure a Payload transceiver.

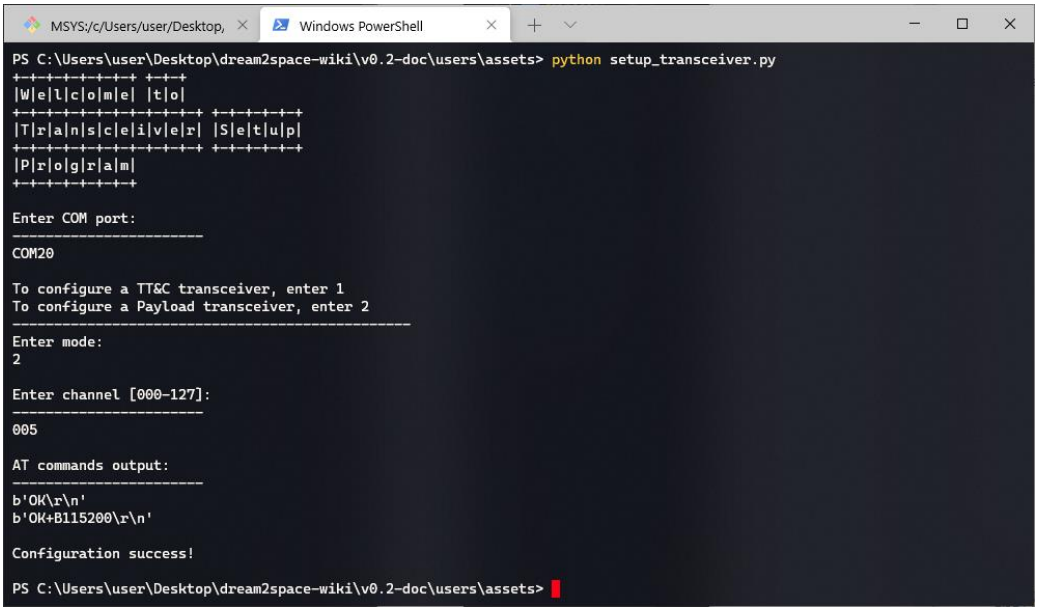
An example and the output are shown in the screenshot below.



Enter the channel that the TT&C transceivers will communicate in and adhere to the format as instructed by the program.

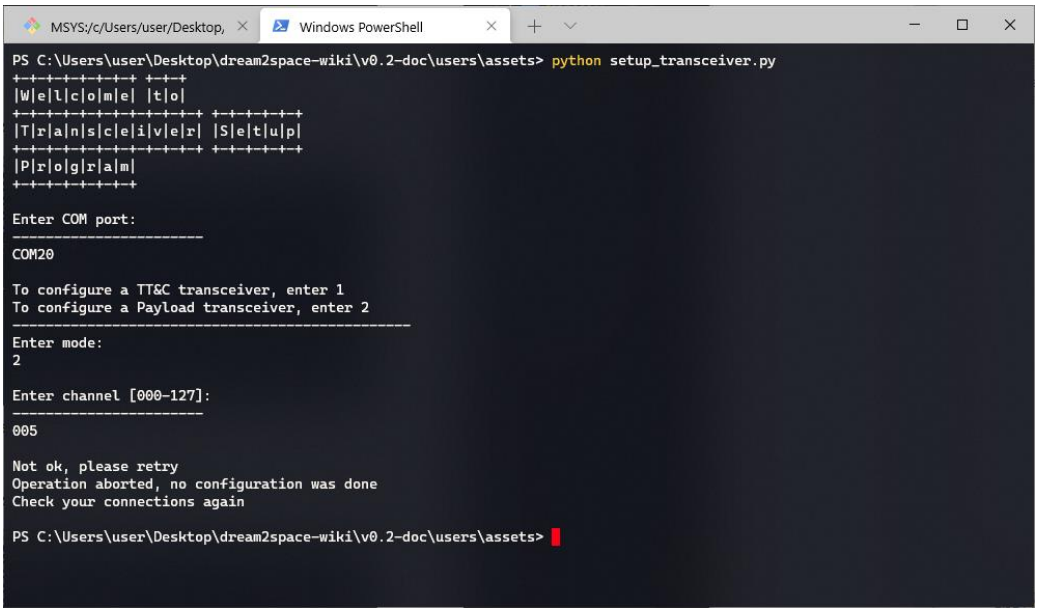
The program will attempt to configure the transceiver and if it is successful, a success message will be

An example and the output are shown in the screenshot below.



Once successful, repeat the step for the other transceiver of the transceiver pair.

If the program is unable to communicate with the transceiver, the error message will be shown as follows.



Here are some tips to troubleshoot before repeating the step for the current transceiver:

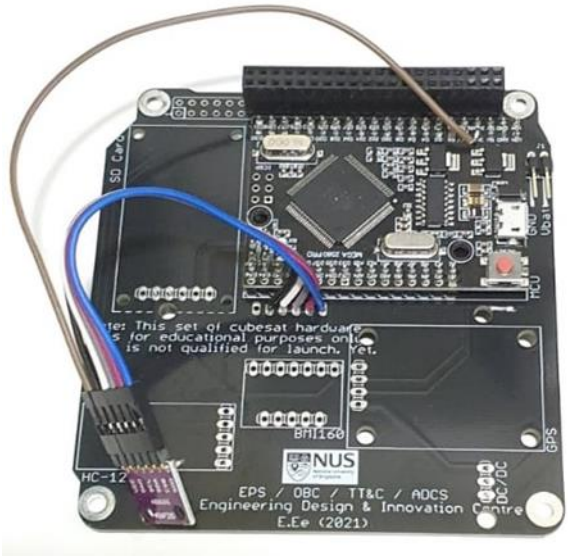
1. Check the connection of the SET pin - ensure it is connected to GND.
2. Ensure that the USB-UART bridge is inserted into the PC.
3. Double check the connections between the USB-UART bridge and transceiver for any loose connections.

⚠ **Note: There are 4 transceivers to be set up in total. When fully assembled, there will be 2 TT&C transceivers (one on a CubeSat PCB and one with a USB-UART bridge on the laptop ground station) and 2 Payload transceivers (one with a USB-UART bridge on the Raspberry Pi and one with a USB-UART bridge on the laptop ground station)**

Setting Up CubeSat Electronics

Items Required

Here is a list of items required to set up the CubeSat Electronics.

Items	Remarks
MicroUSB Cable	Need to support data transfer 
CubeSat Kit Printed Circuit Boards	 * This is the printed circuit board (PCB) of the kit's Electrical Power Subsystem (EPS), 1 of the 5 different boards that will need to be prepared. We will be using the EPS as an example and you will have to do the same for the other boards.
Laptop	

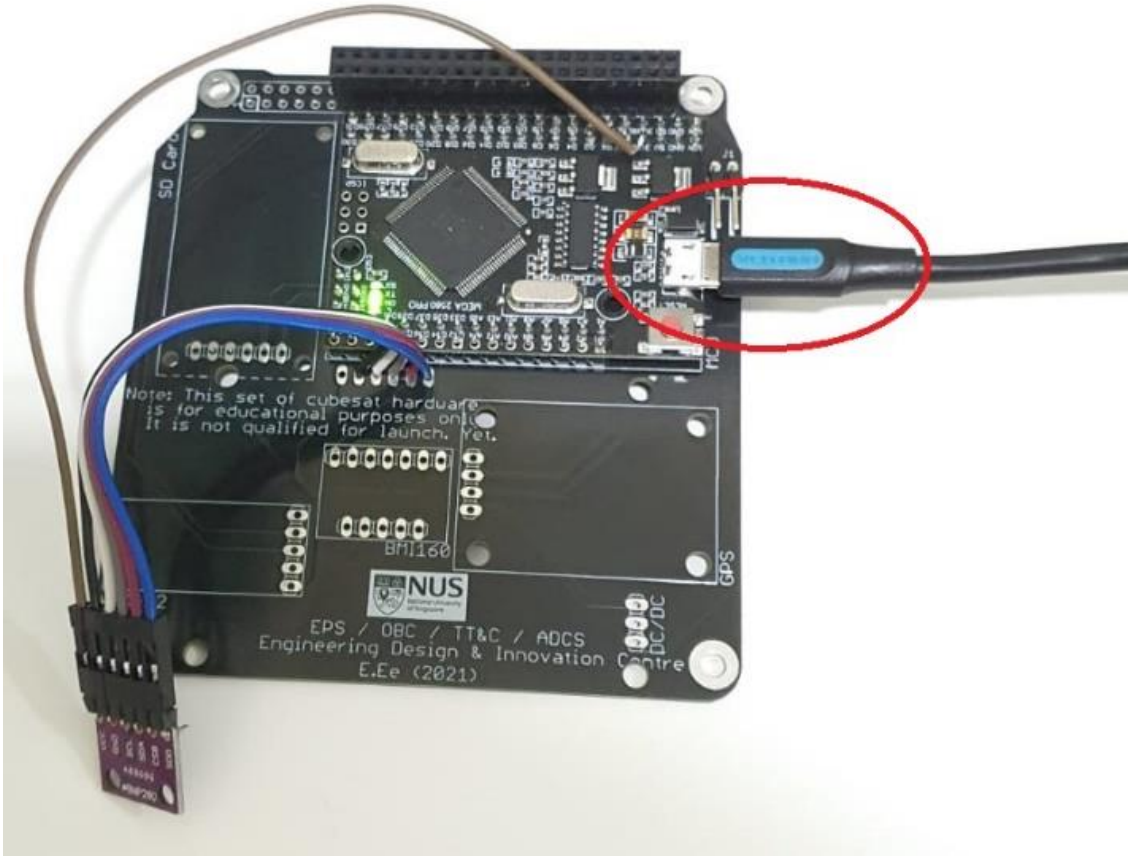
Setup and operations best done on a PC that runs on Windows 10.

Background Idea

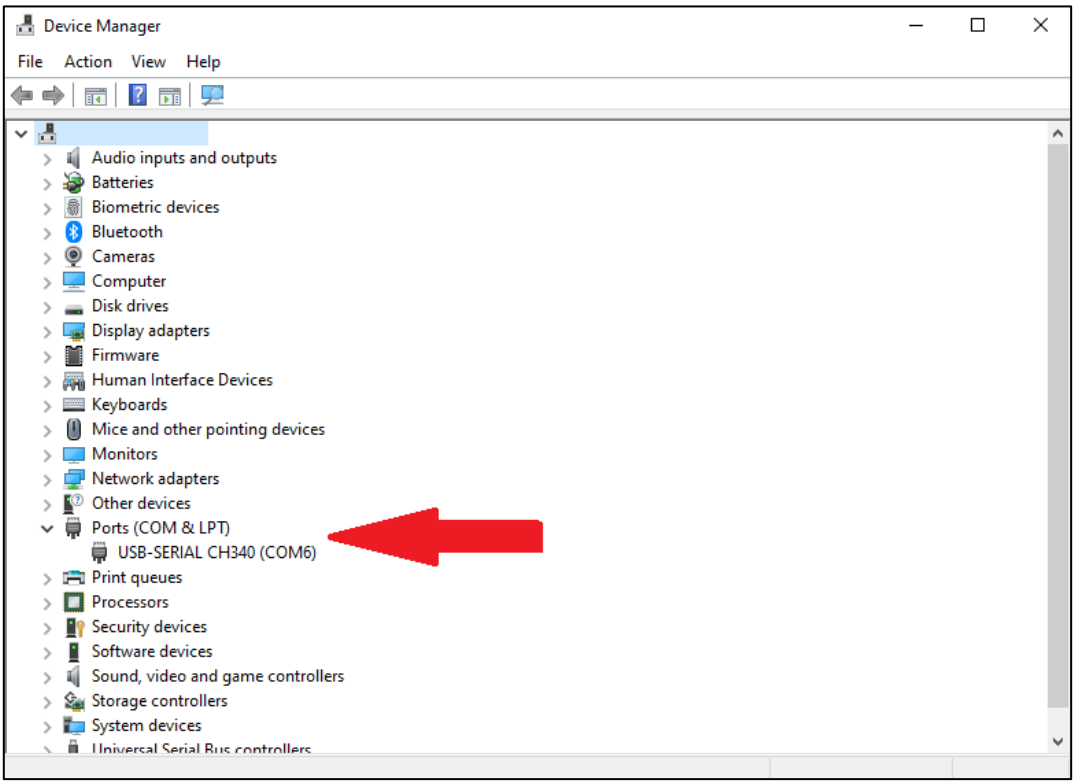
This section will guide the user in familiarizing themselves with the electronics hardware in the CubeSat kit and also cover the setting up of various programs that are required to communicate with the hardware.

Step 1: Setting up the USB drivers

1. Connect USB cable as shown, one end to the micro USB port on the PCB and the other end to a computer, preferably running a windows operating system. Some LEDs will flash to indicate that the board has been powered up.



2. Press the windows key, search and open the device manager. Under Ports (COM & LPT) you should see the USB-SERIAL CH340 has been allocated a COM port, in this case it's COM6. If you see it, skip ahead to step 4, if you don't proceed on to step 3.

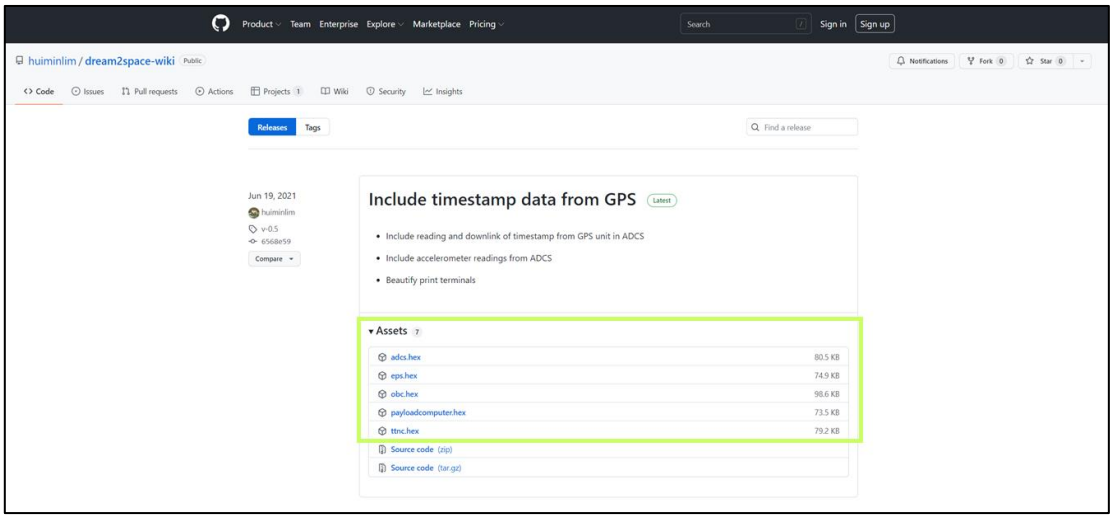


3. If unable to get the COM port up and running, you will need to manually install the USB driver. This tutorial by Sparkfun Electronics (https://learn.sparkfun.com/tutorials/how-to-install-ch340-drivers/all) provides a step-by-step guide on getting it installed. As the bare minimum, it is only required to follow the instructions up to the point where the COM port is detected on the device manager. We will not stop you from trying the loopback test that is documented in the tutorial.

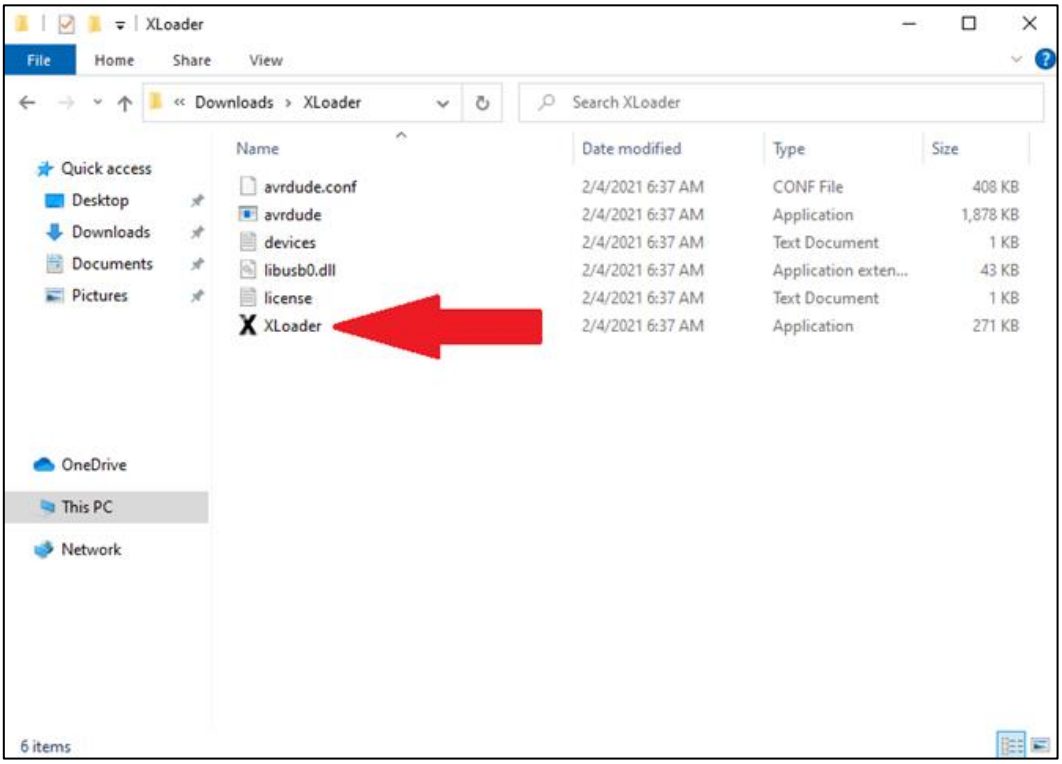
Step 2: Uploading the Firmware

4. It is now time to upload the firmware to the EPS. This will be done through the use of XLoader, an open source program for Windows to upload a .hex file to the EPS. The .hex file is a common method of uploading firmware to a microcontroller (MCU) in this case, we are programming the EPS MCU with a pre written code that has been stored in this format. More information about downloading XLoader can be found on this website by HobbyTronics (https://www.hobbytronics.co.uk/arduino-xloader).

   The .hex files for each subsystem can be found on https://github.com/dream2space/dream2space-wiki/releases/tag/v1.0.0



5. After downloading, extracting the zip, etc, open the XLoader application by double clicking the icon.



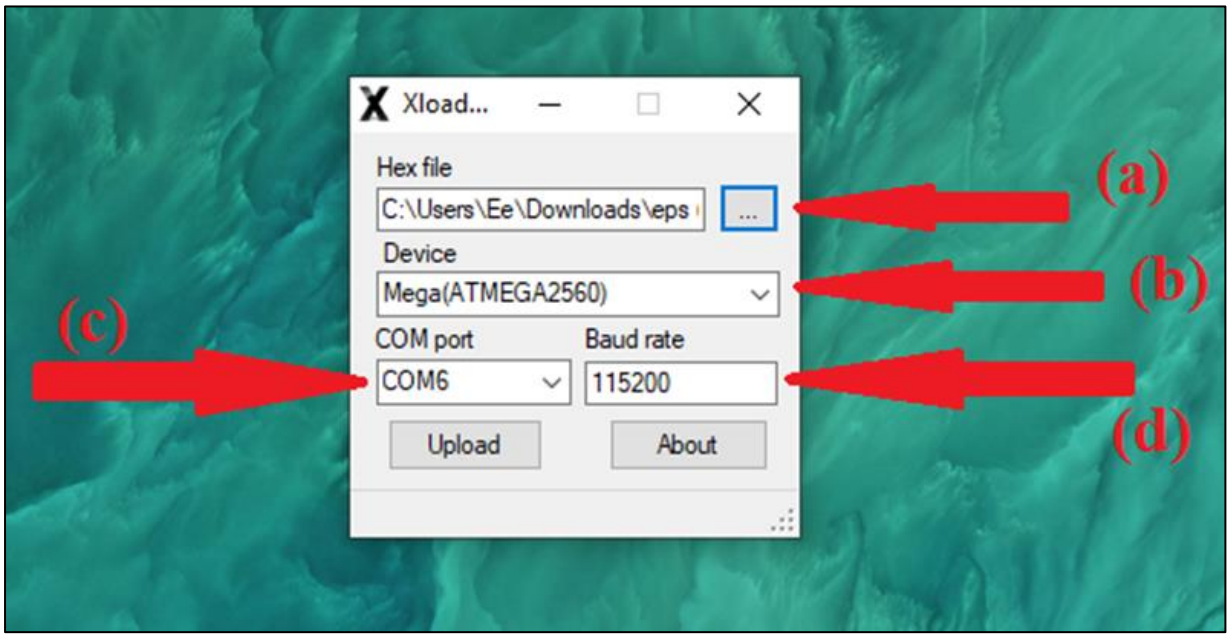
6. Set up the program for our use case by doing the following:

    a) Select the .hex for the correct subsystem, in this case the EPS.

    b) Select the correct device to be programmed, in this case the Mega(ATMEGA2560) which is our target MCU that is being used in this cubesat kit.

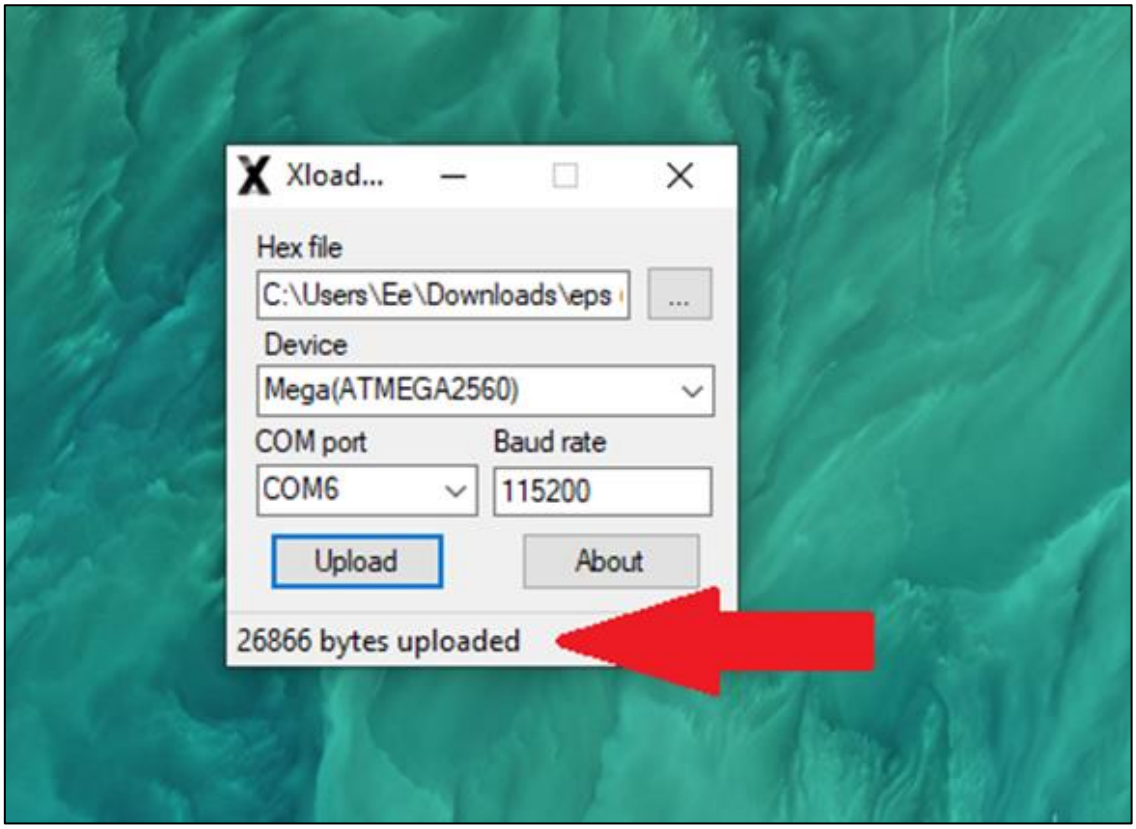
    c) Select the COM port that was detected in step 2. or 3 from the drop down menu.

    d) Set the Baud rate to 115200



⚠ **Note: If you would like to know more about these numbers and settings, we will be happy to chat with you during the lab sessions**

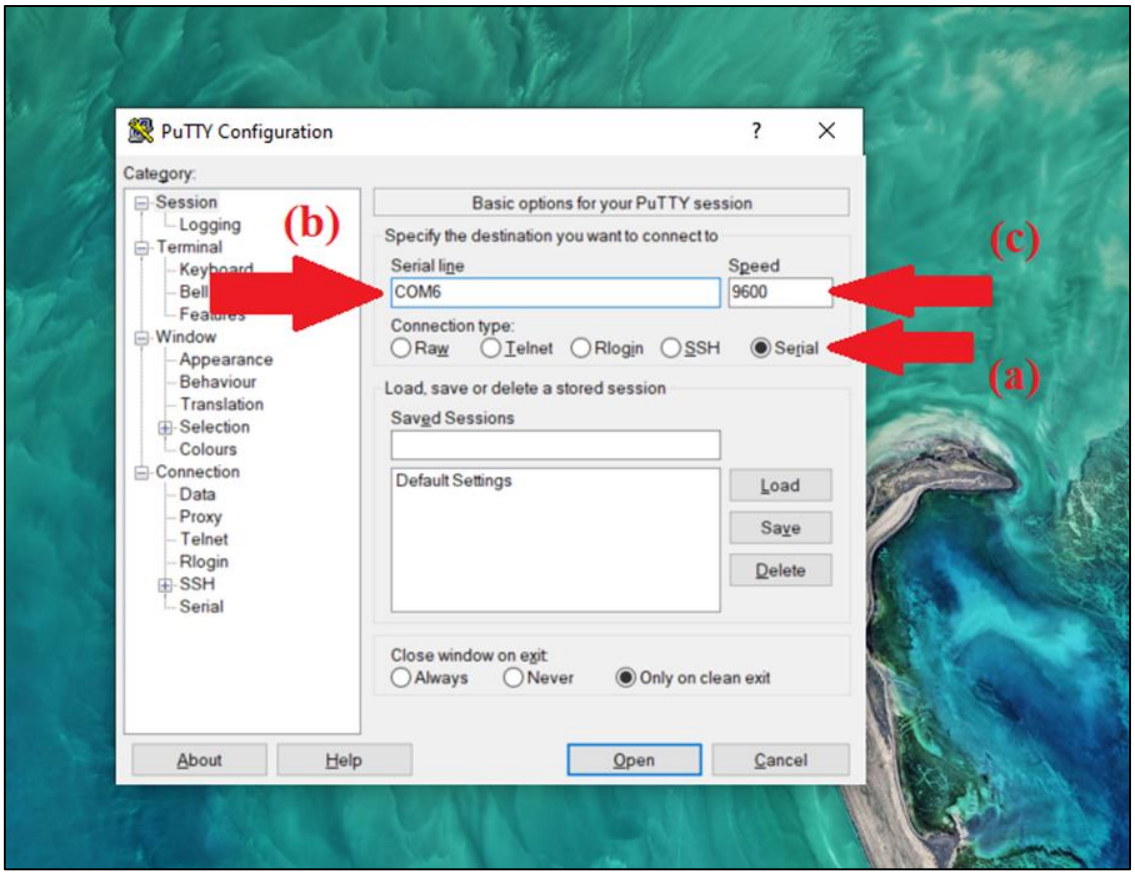
7. Once the above have been set up, click on upload. LED lights on the MCU will flash as the firmware is being uploaded. If successfully uploaded, the program will display the number of bytes uploaded to signal the end of the process. If it takes longer than 20s to perform the upload, it is suspected that there is a mistake and you should consider checking the inputs from step 6.



Step 3: Communicating with Hardware

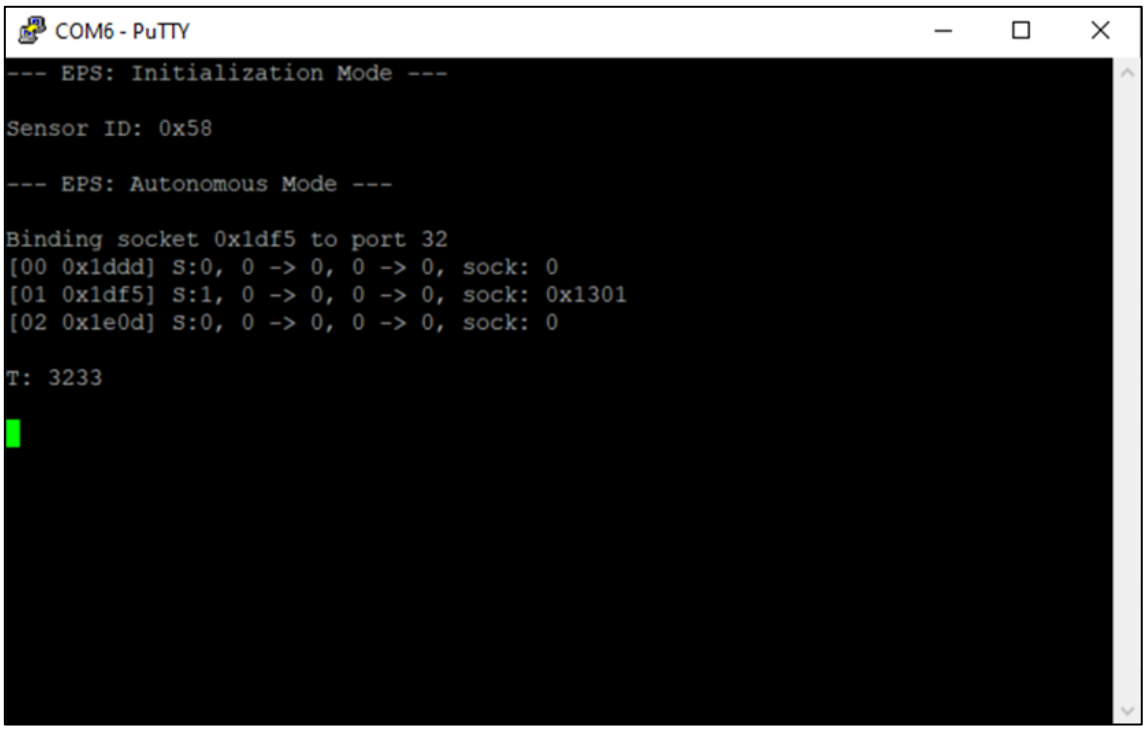
8. To verify that the firmware has been successfully uploaded to the MCU, we will be using a serial console program to “talk” to the EPS. There are many open-source serial console program and the one we will be using for this purpose is PuTTY that was downloaded earlier.

9. We will now have to configure PuTTY. We will first select (a) Serial as the destination we want to connect to, (b) key in the COM port that we had been working with and (c) set the speed to 9600. After setting these, click open to begin communication.



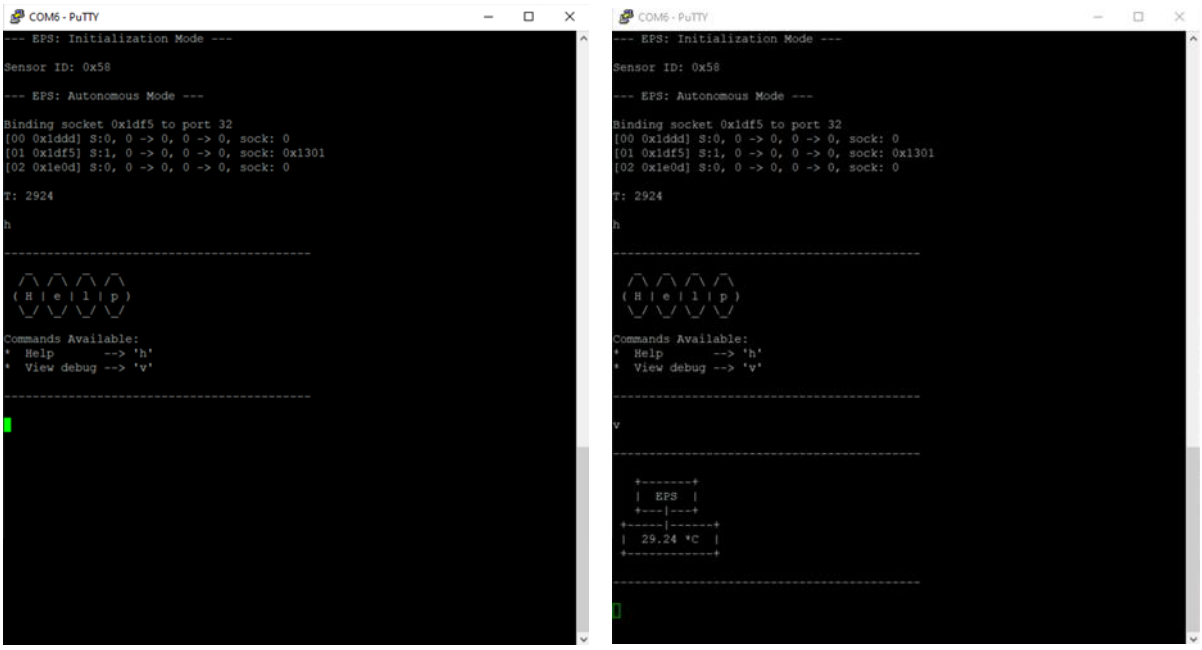
10. If successful, your computer will begin to communicate with the EPS. The image below shows the expected output on the serial console. You should see EPS related data if the correct firmware has been uploaded (see picture below).

    If unsuccessful, you will need to do some debugging. Check if the correct COM port was used, check if the correct speed was used, try to reset the MCU by pressing the red button on the PCB once, reuploading the firmware by repeating steps 4 to 10 again, etc.



11. Typing the letter ‘h’ will open a help screen as shown in the image (left) below. The help screen lists various commands that can be used with the standalone EPS. In this case, letter ‘v’ prints out the battery voltage (if a battery is connected) and the temperature measured by a connected temperature sensor, shown in the image (right) below.

    The data obtained should be sensible eg. A temperature sensor should read somewhere between 18 °C to 31 °C depending on the ambient temperature if a large number or 0 is displayed, there will be a need to figure out if something went wrong.

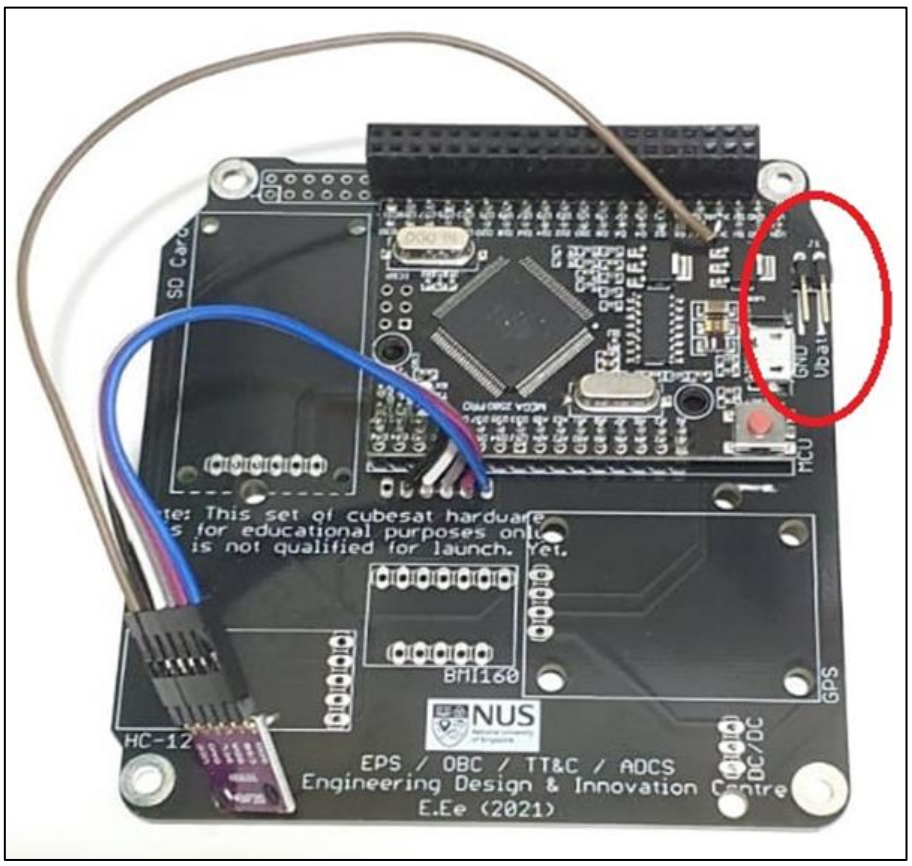


Additional Notes for CubeSat Electronics

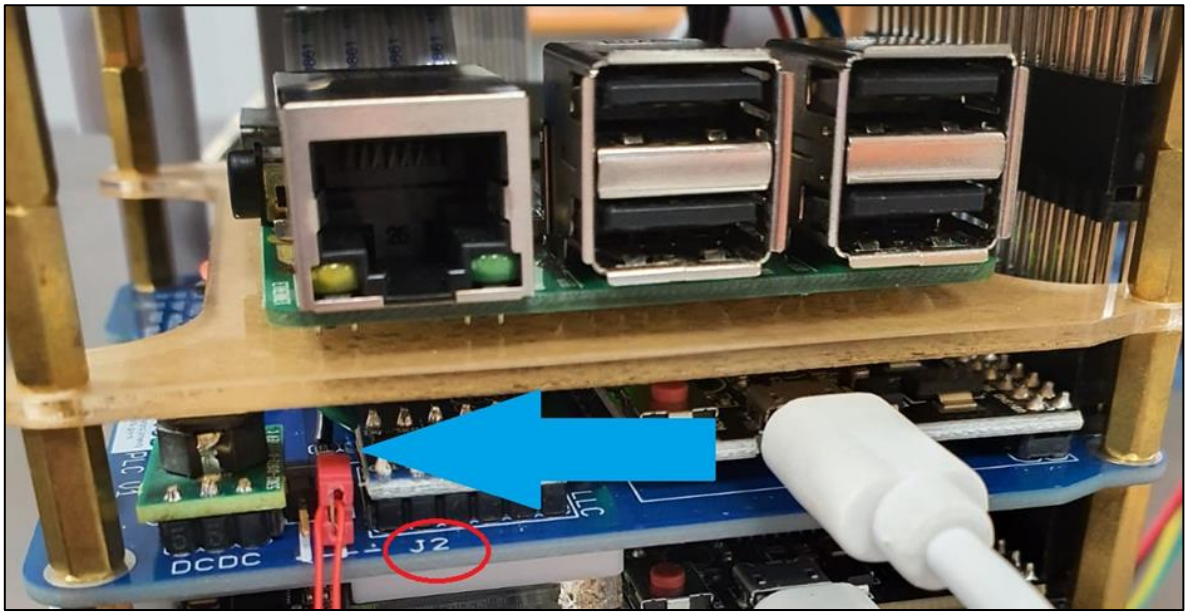
The example provided was only related to the Electrical Power Subsystem and other electronics boards can be set up in a similar fashion.

The CubeSat printed circuit boards (PCB) are to be stacked up and housed inside the structural subsystem. This is documented in the next section and there are multiple ways to do so. However, there will be pros and cons for each particular way things are done.

To power on the satellite after stacking it together, these pins located at connector J1 will be used. When connecting a power source eg. Battery or lab power supply, please ensure that the positive end is attached to the pin labelled Vbatt and the negative end is attached to the pin labelled GND. **Do not supply more than 10V to this connector!!!**



On the payload manager PCB (blue PCB), there is a jumper attached to connector J2. This is a physical switch that turns on the Raspberry Pi when the CubeSat is integrated and powered from the connector J1 either by a battery or a lab power supply. If you need to turn on the Raspberry Pi, you will need to provide power to the satellite stack, remove the jumper and turn it 90 degrees before putting it back into connector J2 to cover up both pins.



Setting Up CubeSat Structure

Items Required

Here is a list of items required to put together the CubeSat structure.

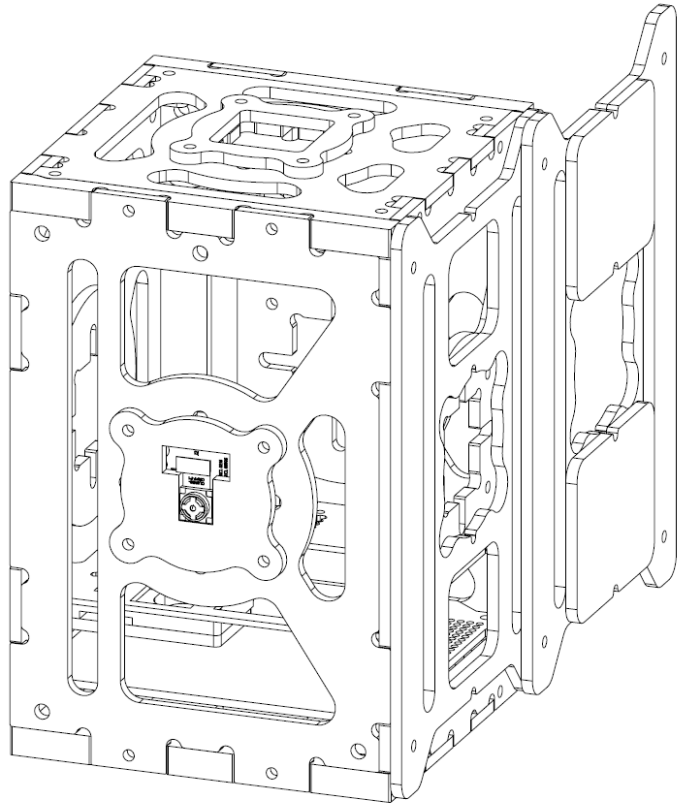
Items	Remarks
Set of 3D printed and laser cut parts	Full list of parts documented in assembly manual

Background Idea

This section will provide an “assembly manual” style set of instructions to put together the CubeSat kit.

CUBE SATELLITE WORKSHOP

MECHANICAL ASSEMBLY MANUAL



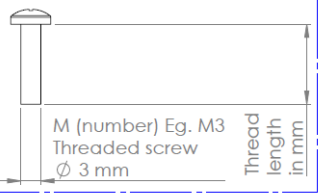
Warning, small and fragile components
Handle with care

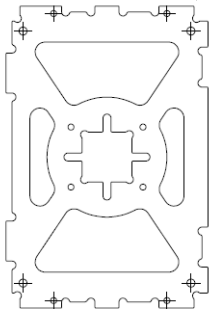
Design by : Brian Shohei Teo
Fabricated : Engineering Design and Innovation Center
Central workshop

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:			FINISH:			DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE				TITLE:	
DRAWN								
CHK'D								
APPV'D								
MFG								
Q.A				MATERIAL:			DWG NO.	A3
							Gen 3 mk 2 pla manual	
				WEIGHT:			SCALE:1:5	SHEET 1 OF 9

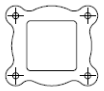
Parts List

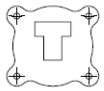
Bolts
M (number) X (Thread length)
(8 pieces) M3 X 5
(28 pieces) M3 X 8
(8 pieces) M3 X 10
(2 pieces) M3 X 15
Nuts
(4 pieces) M3

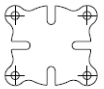


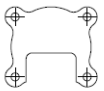

Satellite wall position 1

Accessory mount


GPS cover

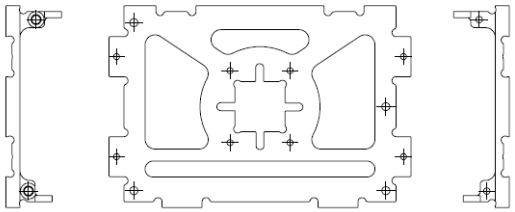

Raspberry Pi cam cover

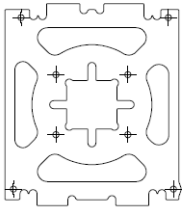

GPS back

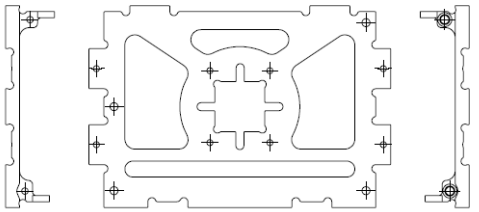

Raspberry Pi cam back

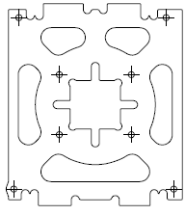
Others

1 X philips screwdriver

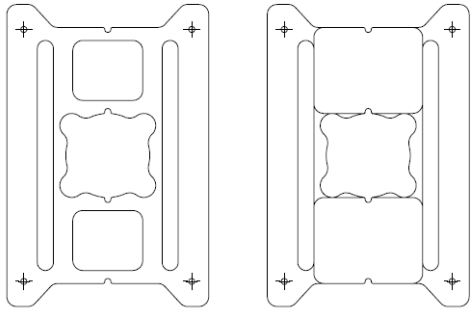


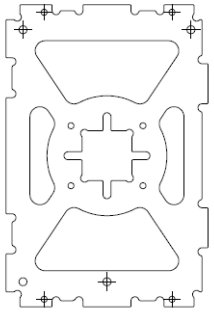

Satellite base plate




Satellite wall top plate

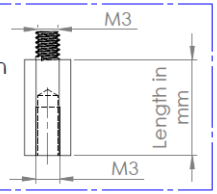
Solar panel and ballast




Satellite wall position 3

Stand-off

(top thread) X (bottom thread), Main length
(4 pieces) M3 X M3, Length 10
(16 pieces) M3 X M3, Length 12
(8 pieces) M3 X M3, Length 15
(4 pieces) M3 X M3, Length 20

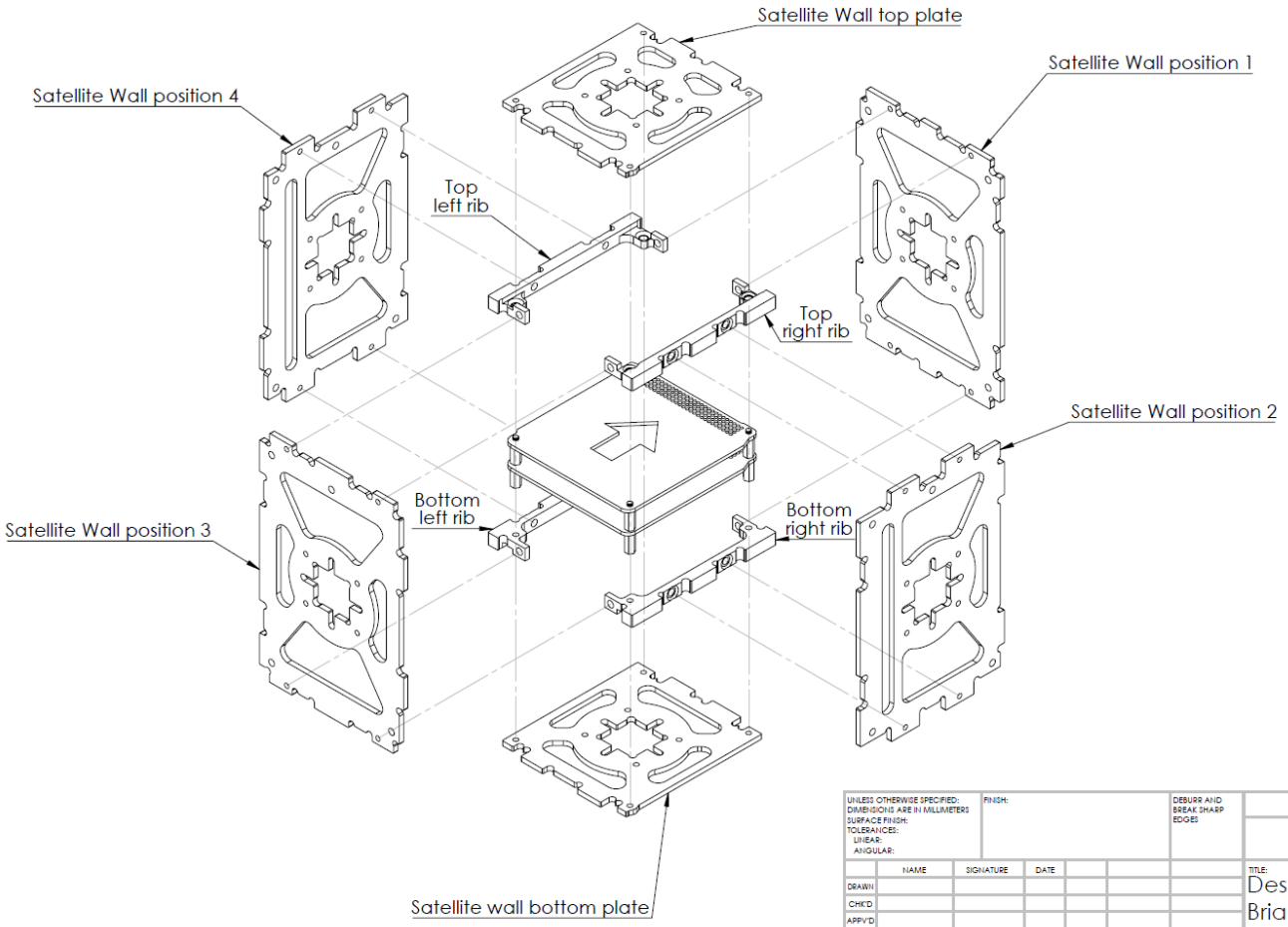


UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION

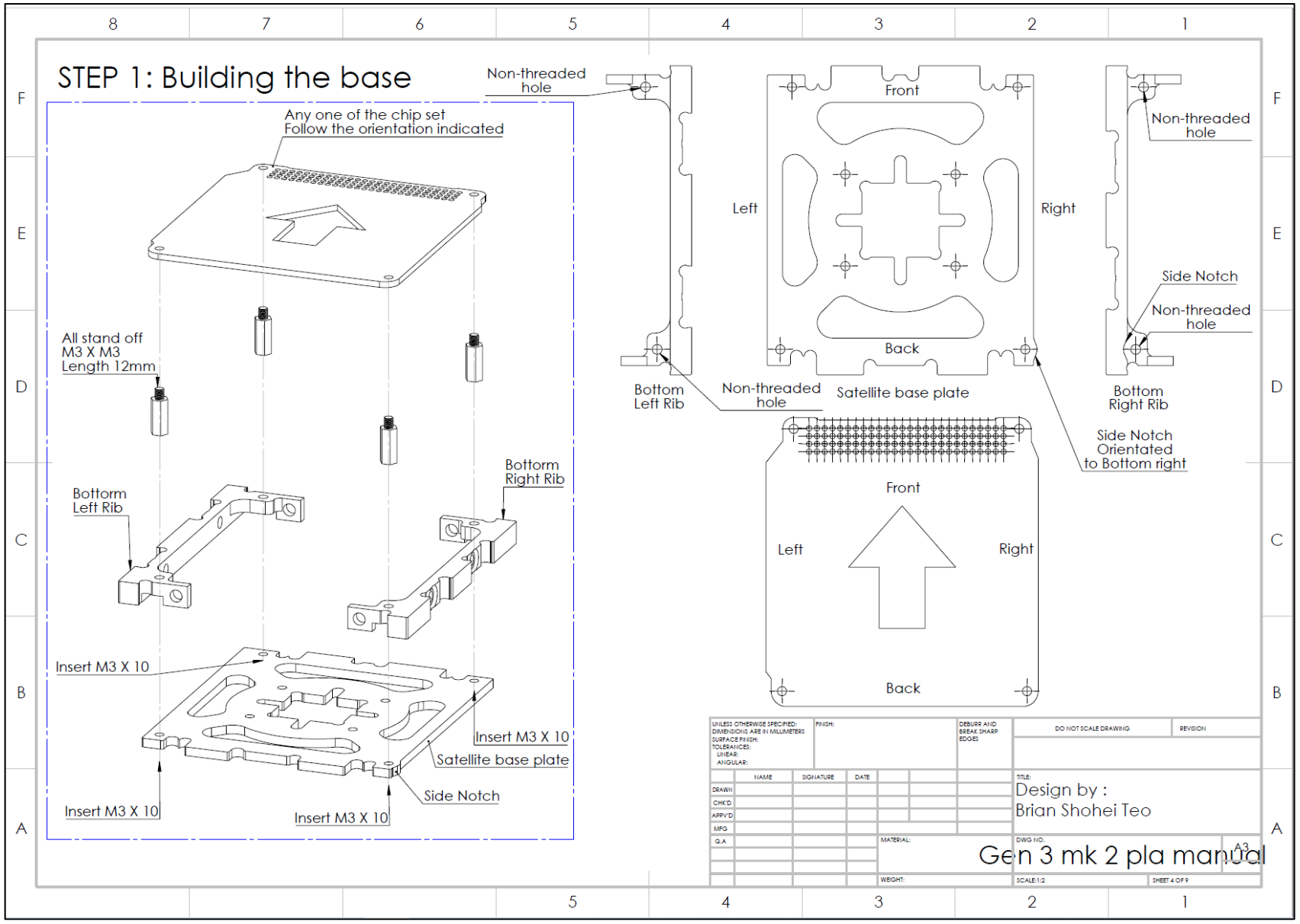
	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL:
WEIGHT:
TITLE:
Design by :
Brian Shohei Teo
DWG NO.
Gen 3 mk 2 pla manual
A3
SCALE:1:1
SHEET 2 OF 9

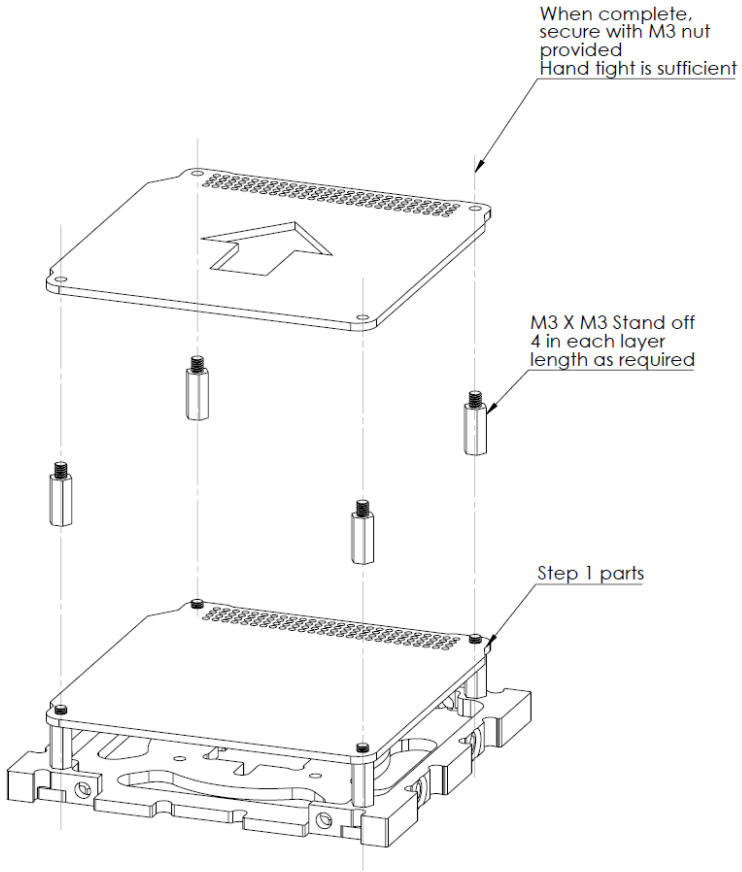
Exploded view of assembly (no accesories)



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:		DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE		TITLE: Design by : Brian Shohei Teo
DRAWN					
CHK'D					
APPV'D					
MFG					
Q.A				MATERIAL:	DWG NO. Gen 3 mk 2 pla manual / A3
				WEIGHT:	SCALE:1:2 / SHEET 3 OF 9


STEP 1: Building the base
Any one of the chip set
Follow the orientation indicated
All stand off
M3 X M3
Length 12mm
Bottom
Left Rib
Bottom
Right Rib
Insert M3 X 10
Insert M3 X 10
Insert M3 X 10
Insert M3 X 10
Satellite base plate
Side Notch
Non-threaded
hole
Front
Left
Right
Back
Bottom
Left Rib
Non-threaded
hole
Satellite base plate
Non-threaded
hole
Side Notch
Non-threaded
hole
Bottom
Right Rib
Side Notch
Orientated
to Bottom right
Front
Left
Right
Back
Design by :
Brian Shohei Teo
Gen 3 mk 2 pla manual
A3

STEP 2: Stack up the Printed Circuit Boards



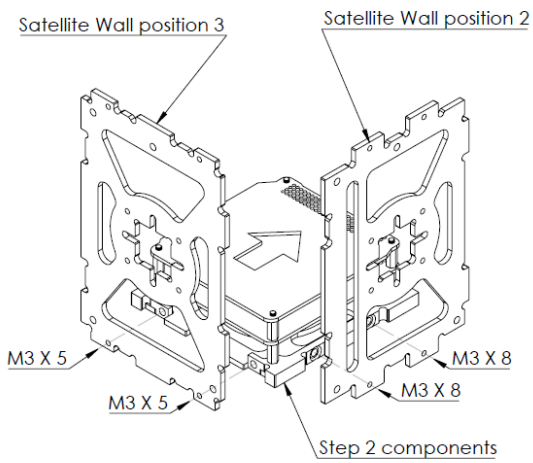
Printed Boards Provided
(refer to electronics manual for usage)

1. Electronic Power System (EPS)
2. On-Board Computer (OBS)
3. TT & C
4. ADCS
5. PLM

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:		DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION	
	NAME	SIGNATURE	DATE		TITLE: Design by : Brian Shohei Teo		
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:	DWG NO. Gen 3 mk 2 pla manual		A3
				WEIGHT:	SCALE:1:2	SHEET 5 OF 9	

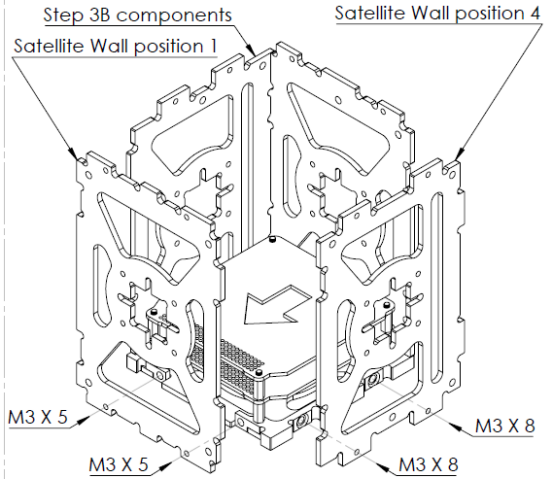
STEP 3: Mount on side panels

STEP 3A: Mount on wall 2 & 3

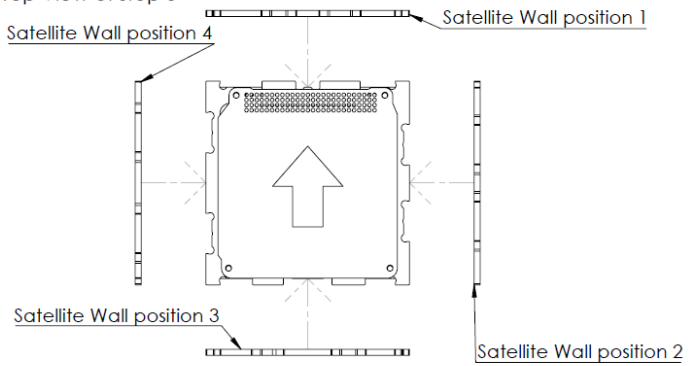


Rotate by 180°
Temporarily

STEP 3B: Mount on wall 1 & 4



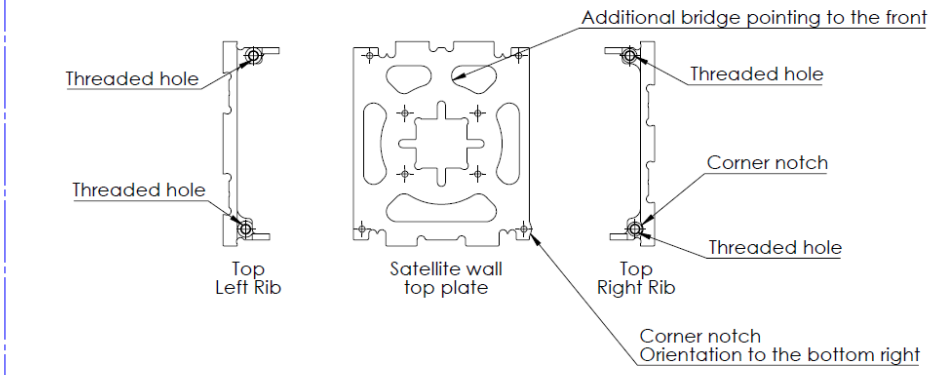
Top View of step 3



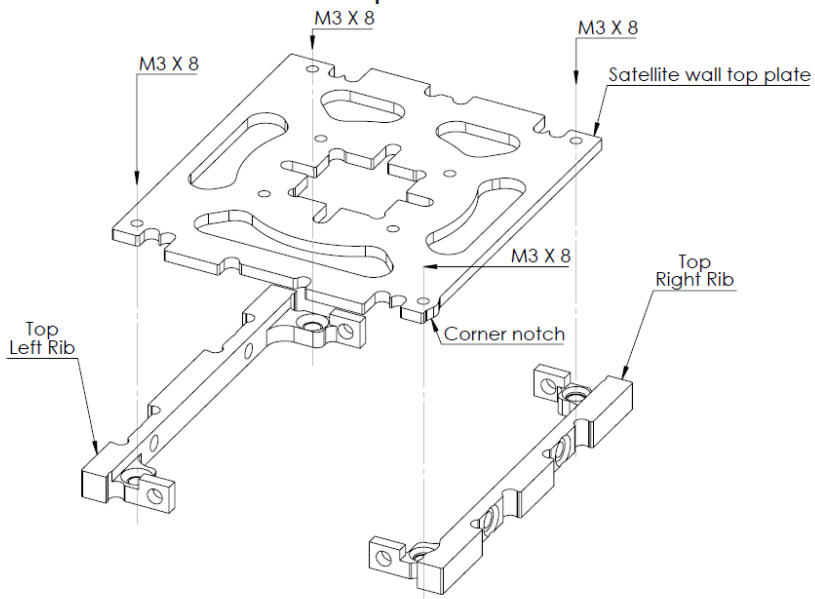
Rotate the object back to Step 3A orientation once complete

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE				TITLE: Design by : Brian Shohei Teo	
DRAWN								
CHK'D								
APPV'D								
MFG								
Q.A				MATERIAL:			DWG NO. Gen 3 mk 2 pla manual	A3
				WEIGHT:			SCALE:1:2	SHEET 6 OF 9

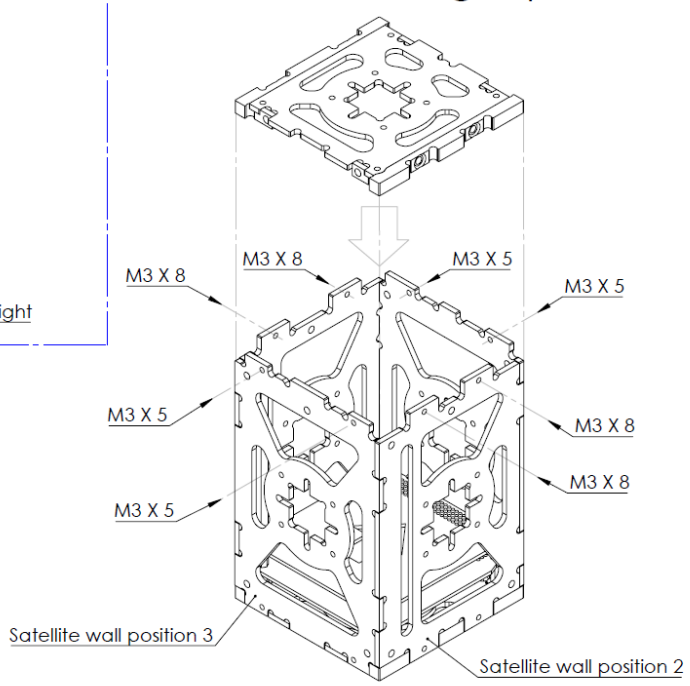
STEP 4: Mount upper assembly



STEP 4A: Assemble top cover



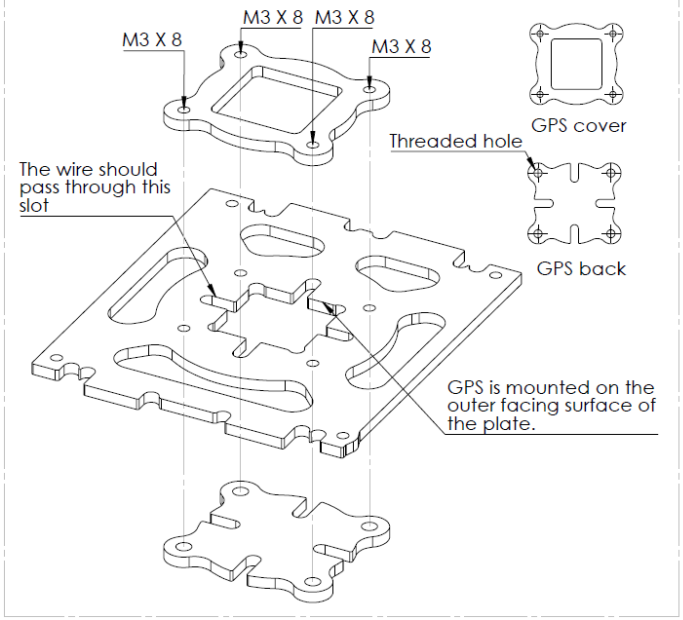
STEP 4B: Mounting top cover



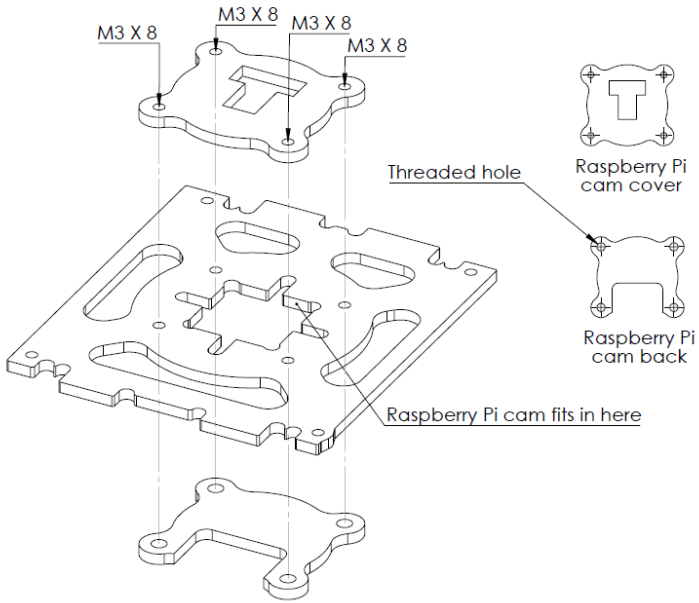
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:		DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE	TITLE: Design by : Brian Shohei Teo	
DRAWN					
CHK'D					
APPV'D					
MFG					
Q.A				MATERIAL:	DWG NO. Gen 3 mk 2 pla manual A3
				WEIGHT:	SCALE:1:2 SHEET 7 OF 9

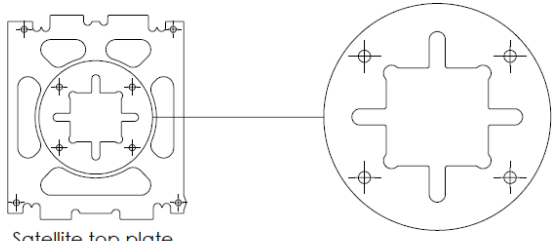
Optional step A: Mounting of GPS and Raspberry Pi cam

GPS accessory mount



Raspberry Pi Cam accessory mount



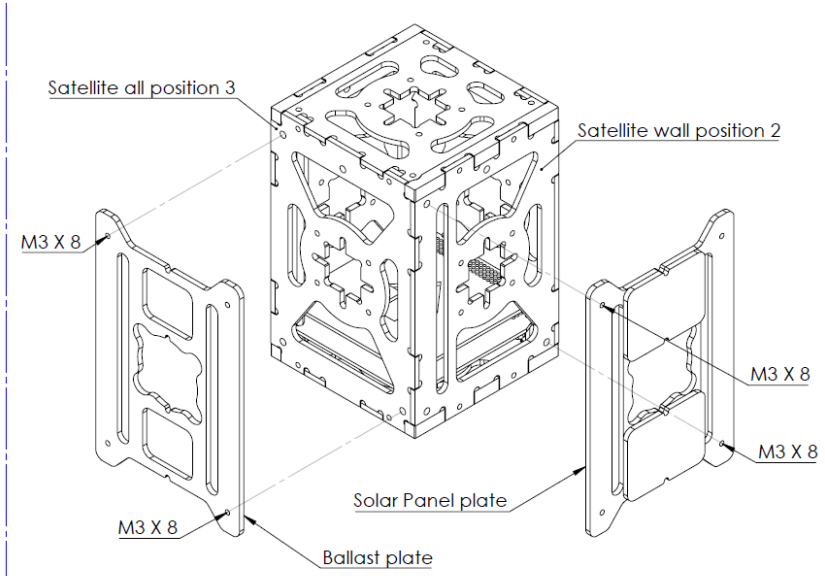


Any wall with Detail H can be used to mount the Raspberry Pi Cam and the GPS

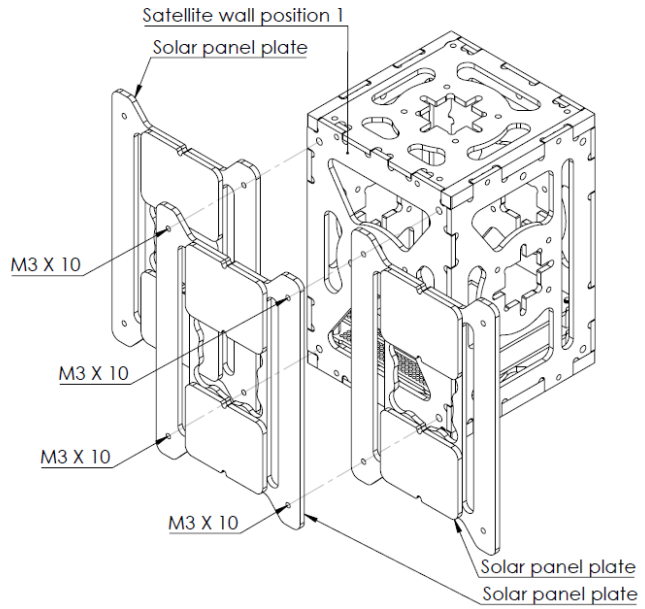
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:		DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE		TITLE: Design by : Brian Shohei Teo
DRAWN					
CHK'D					
APPV'D					
MFG					
Q.A				MATERIAL:	DWG NO. Gen 3 mk 2 pla manual A3
				WEIGHT:	SCALE:1:1 / SHEET 8 OF 9

Optional step B: Mounting of Solar panel and ballast plate

Ballast plate and Solar panel mount



Solar panel mount



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:			DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE			TITLE: Design by : Brian Shohei Teo
DRAWN						
CHK'D						
APPV'D						
MFG						
Q.A				MATERIAL:		DWG NO. Gen 3 mk 2 pla manual / A3
				WEIGHT:		SCALE:1:2 / SHEET 9 OF 9

Setting Up CubeSat Ground Station

Items Required

Here is a list of items required to set up the CubeSat Ground Station.

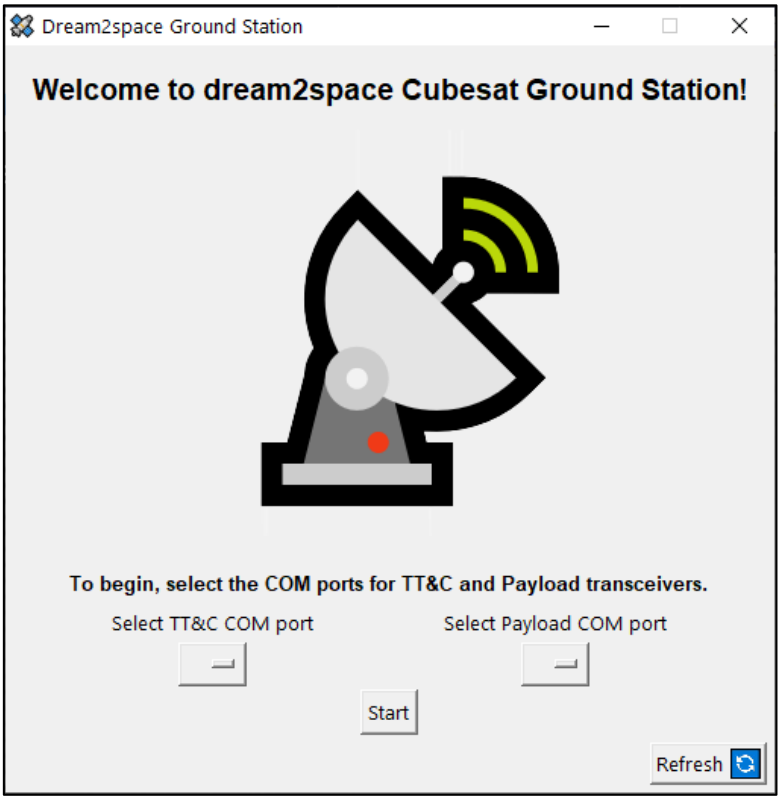
Items	Remarks
Fully Assembled CubeSat	To be done following the instructions above
Laptop	Requires Python3 installed

Setup and operations were tested on a PC that runs on Windows 10.

Background Idea

The Dream2space GUI Ground Station allows you to interact with CubeSat that was built in the previous sections.

The Ground Station app is currently on available on Windows Operating System.



Prerequisites

This step is needed if you are using a computer that runs on a **Windows** operating system.

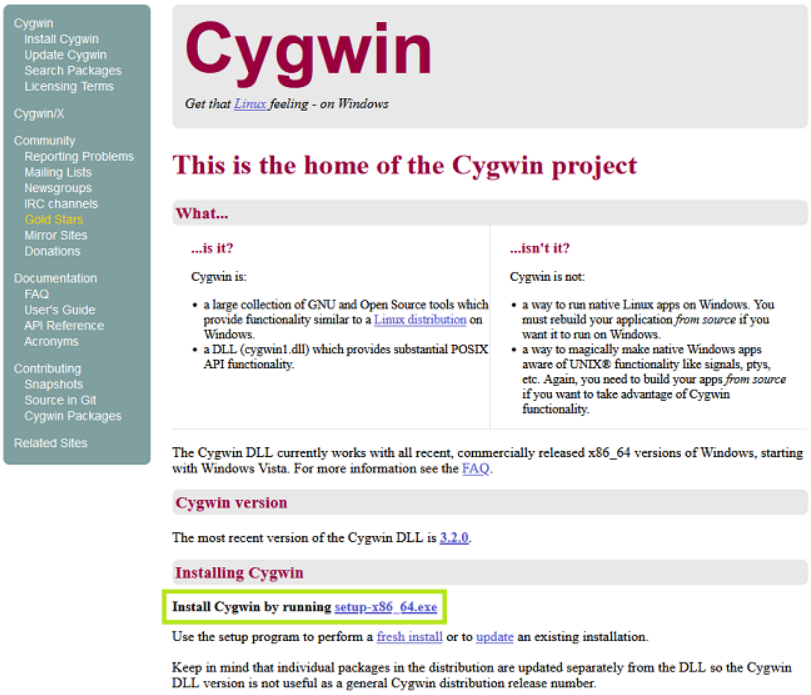
The Ground Station app requires an additional software **Cygwin** to run.

Step 1: Visit the Cygwin website

To download Cygwin, click the link here.

Link to download Cygwin: https://www.cygwin.com/

The Cygwin page should look like this:



Step 2: Download Cygwin installer

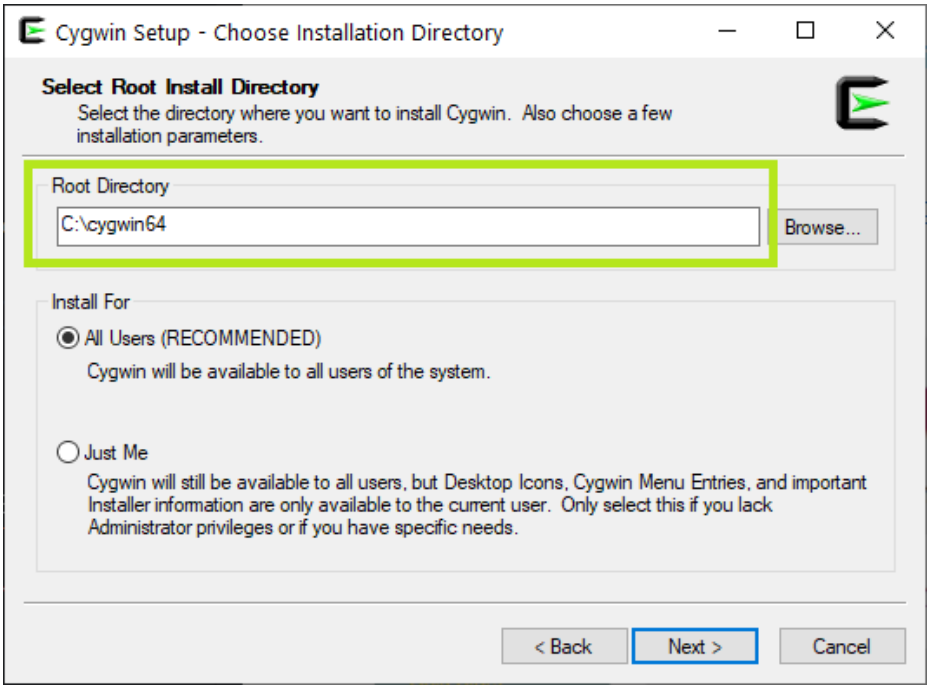
Click on the link `setup-x86_64.exe` to download the Cygwin installer, as shown in the **green** box in the screenshot above.

Step 3: Install Cygwin

Proceed to install Cygwin using the installer.

When prompted to choose the Installation Directory, ensure that the Root Directory is `C:\cygwin64`.

The step and the correct Root Directory are shown in the **green** box in the screenshot below.



Getting Started

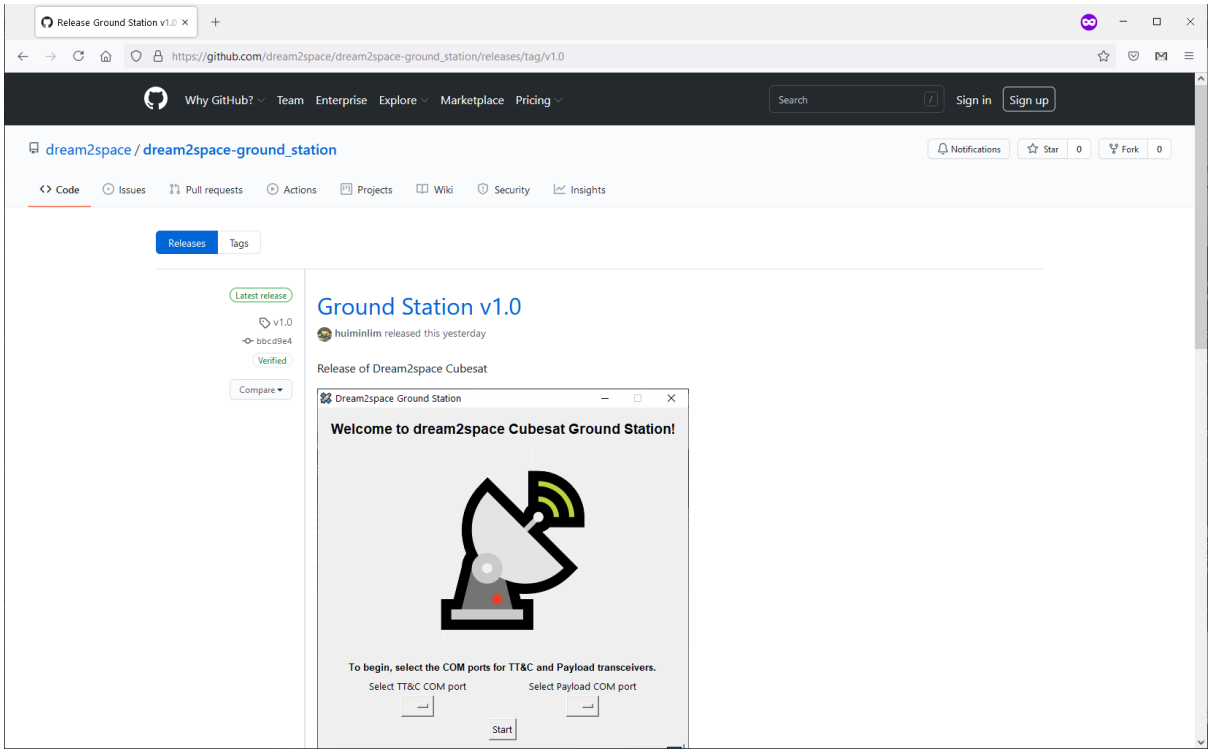
Step 1: Download the Ground Station app

To begin, download the Ground Station app.

Download the latest version of the Ground Station Ground_Station.exe from the Releases page, link below:

https://github.com/dream2space/dream2space-ground_station/releases/tag/v1.0

The Releases page should look like this:

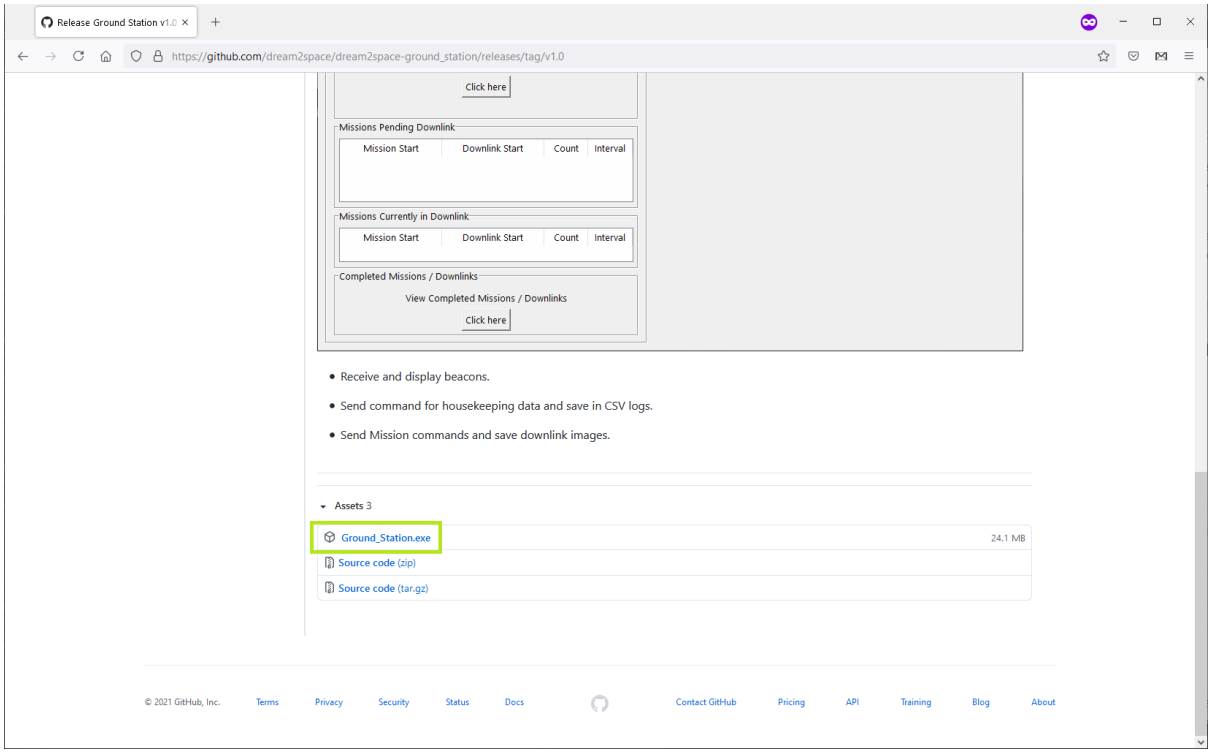


You can find the latest version of the Ground Station app and the Version tag in the table below.

Executable Name	Version Number
Ground_Station.exe	v1.0

Scroll down to view the download link of the Ground_Station.exe app.

The download link of the Ground_Station.exe app is boxed in **green** box in the screenshot below.



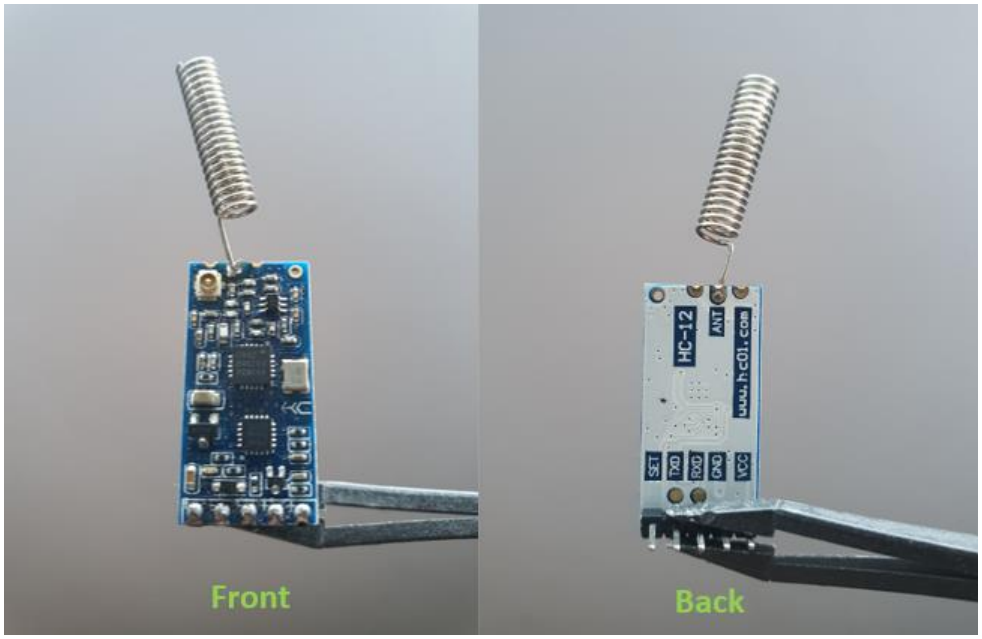
Click on the Ground_Station.exe under the **Assets** section to download it.

⚠ **Note: Steps 2 to 4 serve as a reminder if these were not already set up previously.**

Step 2: Setup the Ground Station transceivers

The Ground Station has two 433 MHz transceivers to communicate with the TT&C and the Payload of the Dream2space Cubesat respectively.

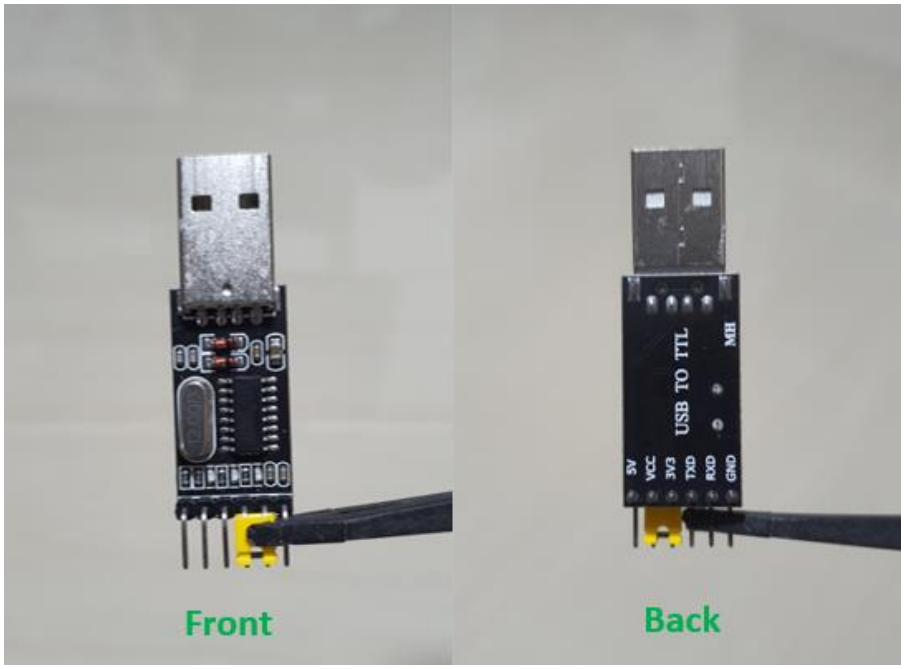
This is how a transceiver looks like:



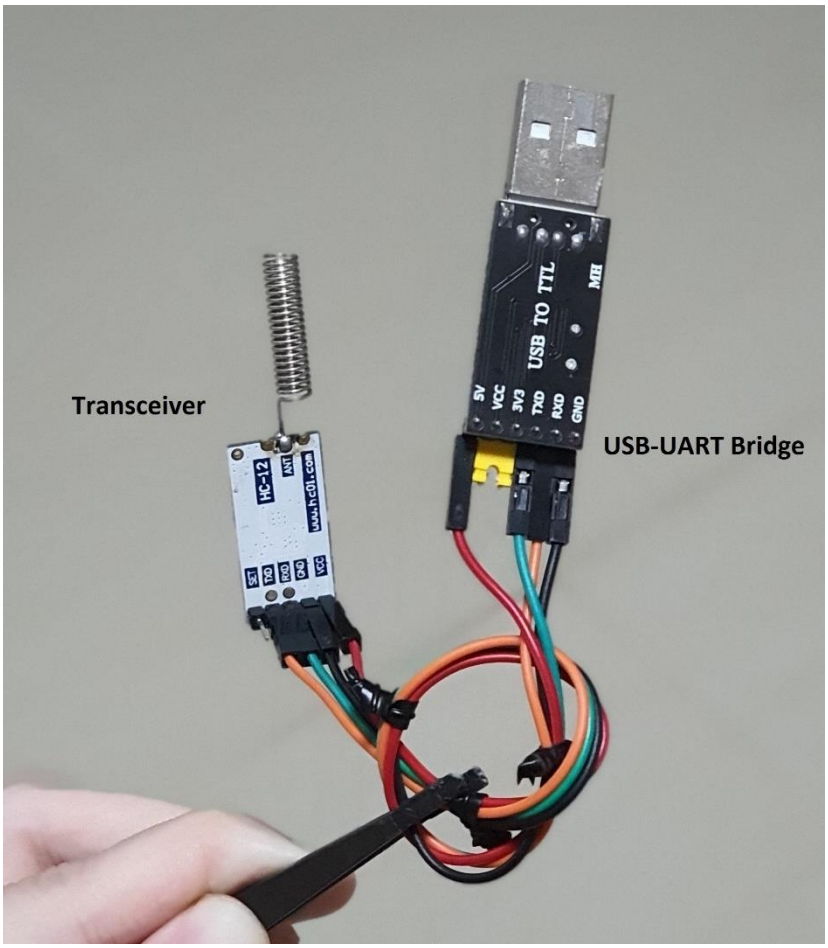
The transceiver uses the Universal asynchronous receiver-transmitter (UART) protocol to send data to and from the transceiver.

As most computers are unable to communicate via UART directly, a USB-UART bridge to connect the transceiver to the computer's USB ports.

This is how a USB-UART bridge looks like:



An example of the transceiver connected to the USB-UART bridge that you have received is shown below:



Double check that the pin connections are done as shown in the table below:

USB-UART bridge	Transceiver
5V	Vcc
GND	GND
TX	RX
RX	TX

This table is also a handy reference if the connections are removed by mistake!

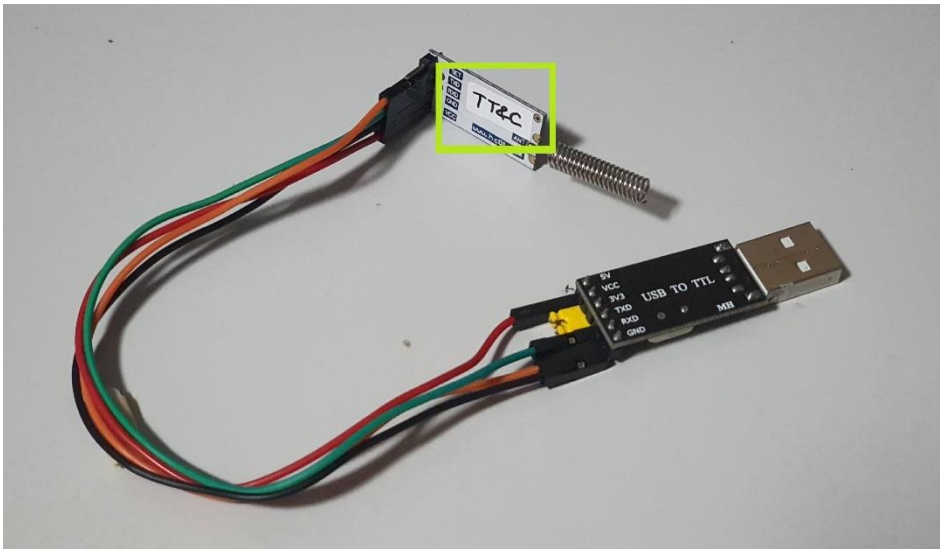
Step 3: Connect the TT&C transceiver to the computer

⚠ **The sequence of plugging in the USB-UART bridges is important.**
Do try to follow the sequence.

The computer identifies the USB-UART bridges as virtual COM ports and each bridge is assigned a unique COM port number upon plugging in the USB.

The Ground Station app needs to know COM port number for the TT&C and Payload transceiver to read and write to the respective transceivers.

The TT&C transceiver comes with a label on the transceiver, as shown in the image below.



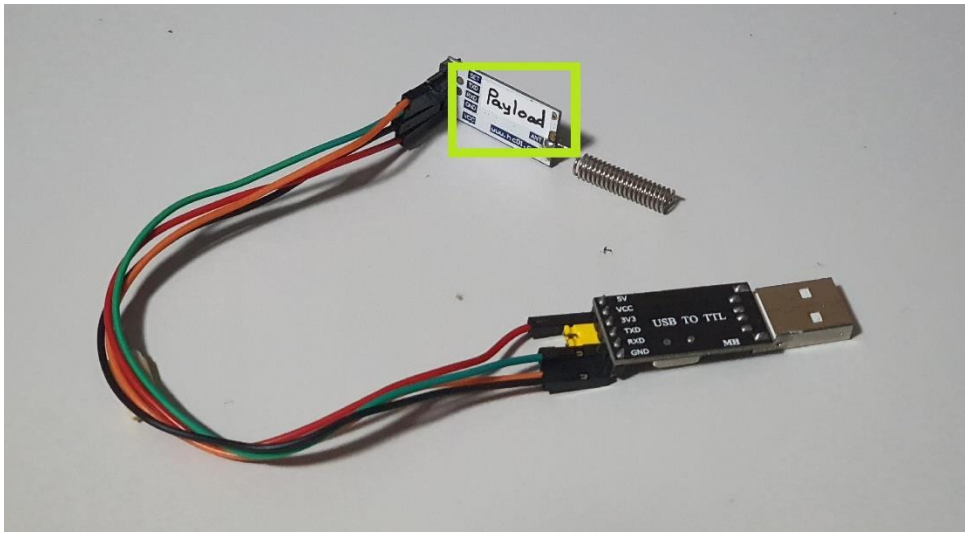
Plug in the TT&C transceiver's USB-UART bridge into the computer. The computer should detect the USB COM port and the COM port can be found using the Device Manager.

Note down the COM port for the TT&C transceiver's USB-UART bridge.

Step 4: Connect the Payload transceiver to the computer

⚠ **The sequence of plugging in the USB-UART bridges is important.**
Do try to follow the sequence.

The payload transceiver comes with a label on the transceiver, as shown in the image below.



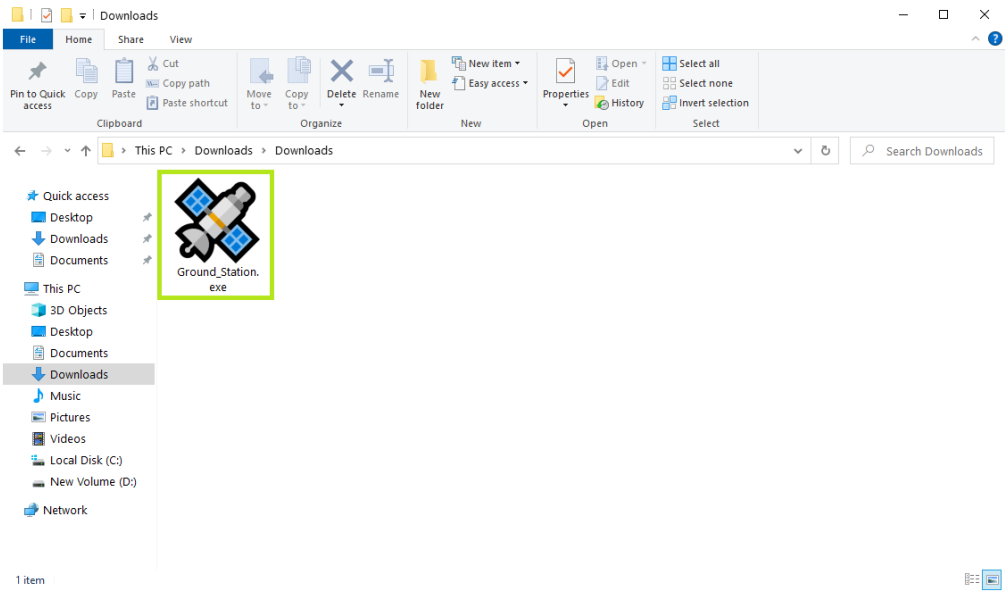
Plug in the Payload transceiver's USB-UART bridge into the computer. The computer should detect the USB COM port and the COM port can be found using the Device Manager.

Note down the COM port for the Payload transceiver's USB-UART bridge.

Step 5: Open up the Ground Station app

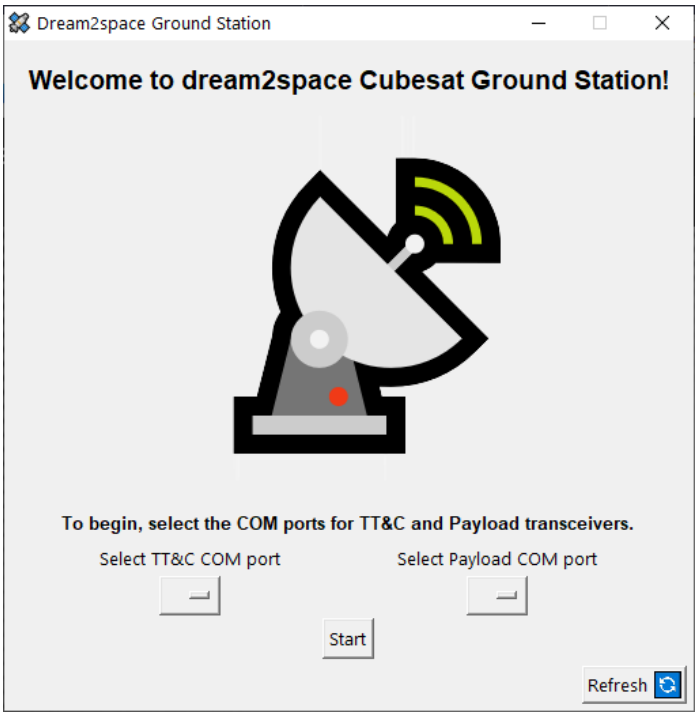
⚠ **This is the recommended way to open up the GUI exe.**
Other methods may cause errors.

Navigate to the folder containing the downloaded app, as shown in the folder below.



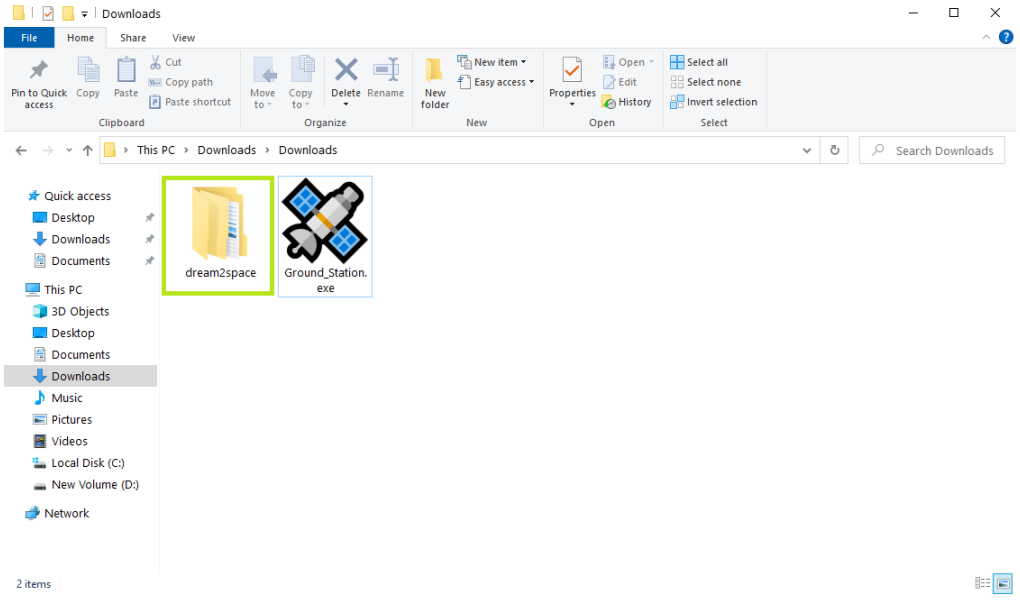
Double click on the icon to launch the app. The icon is boxed in **green** in the screenshot below.

If the app has launched successfully, the Start Page, as shown in screenshot below, will appear.



A dream2space folder will also be created in the same folder to store data collected from the app.

The folder is boxed in **green** in the screenshot below.



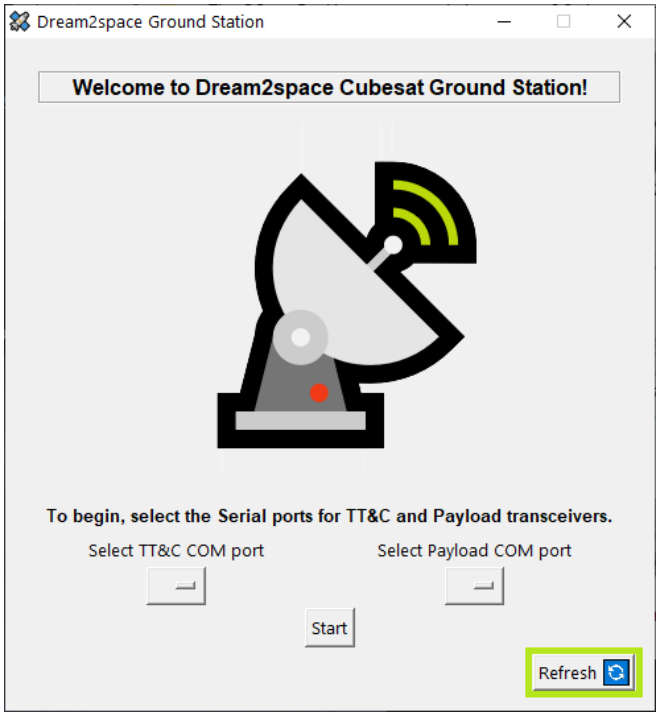
⚠ **Do not delete that folder while the app is running!**

Configuring the Ground Station

TIP!

If you cannot spot the COM ports noted down in previous steps, try clicking on the Refresh button.

The Refresh button is boxed in **green** in the screenshot below.



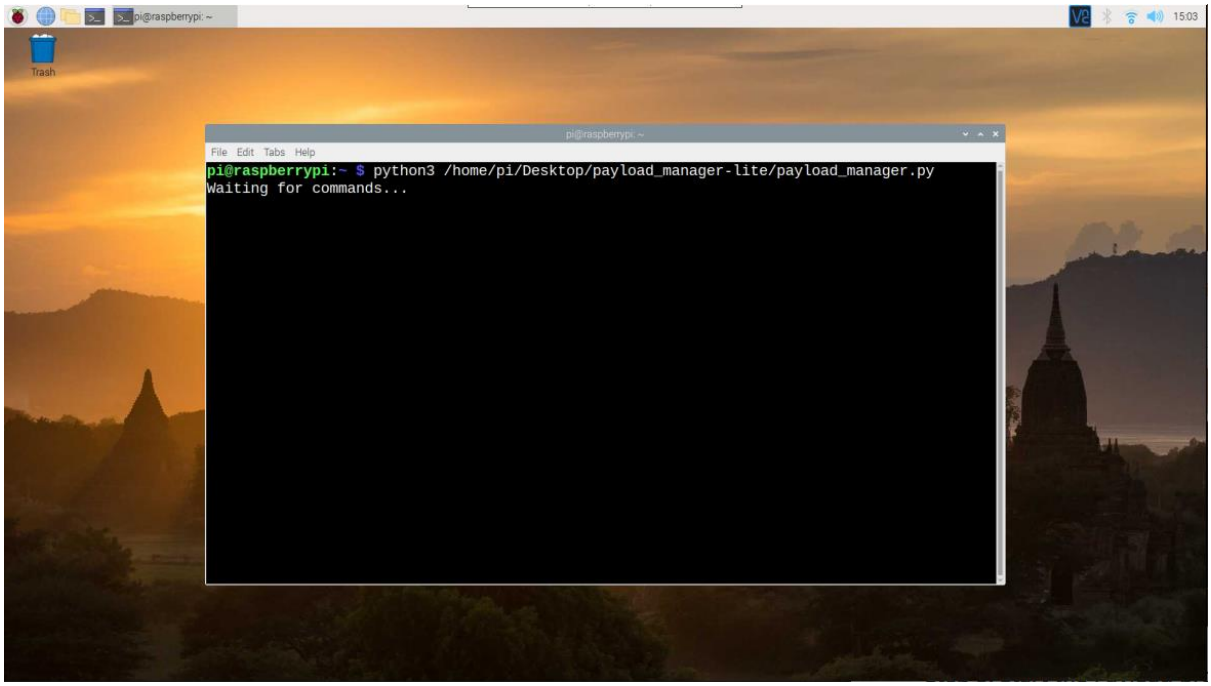
The Refresh button will scan and reload the available COM ports again.

As the ground station works together with the other CubeSat hardware, the payload program which was installed right at the start of this manual needs to be running on the Raspberry Pi.

This can be done by typing the following command exactly into the Terminal window if using a monitor or through the PuTTY interface.

```
python3 /home/pi/Desktop/payload_manager-lite/payload_manager.py
```

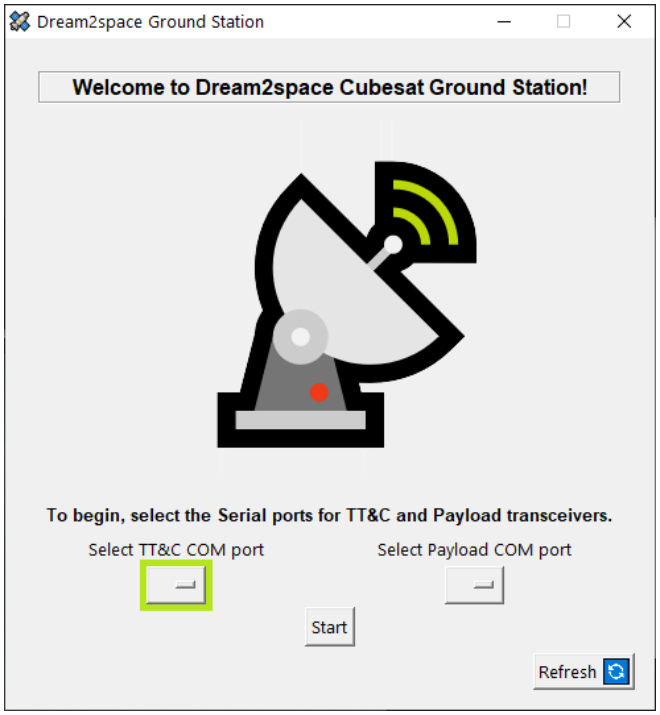
Once the command has run successfully, the Terminal window will display the following output to wait for new Commands from the Cubesat.



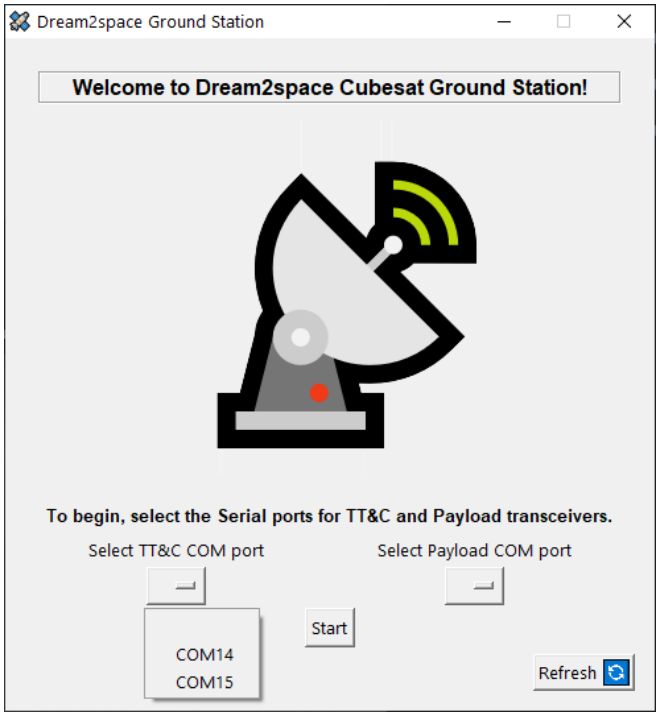
Step 1: Select the TT&C COM port

To view the list of COM ports available for selection as the TT&C transceiver's port, click on the dropdown menu.

The dropdown menu is boxed in **green** in the screenshot below.



The list of discovered COM ports will be displayed.

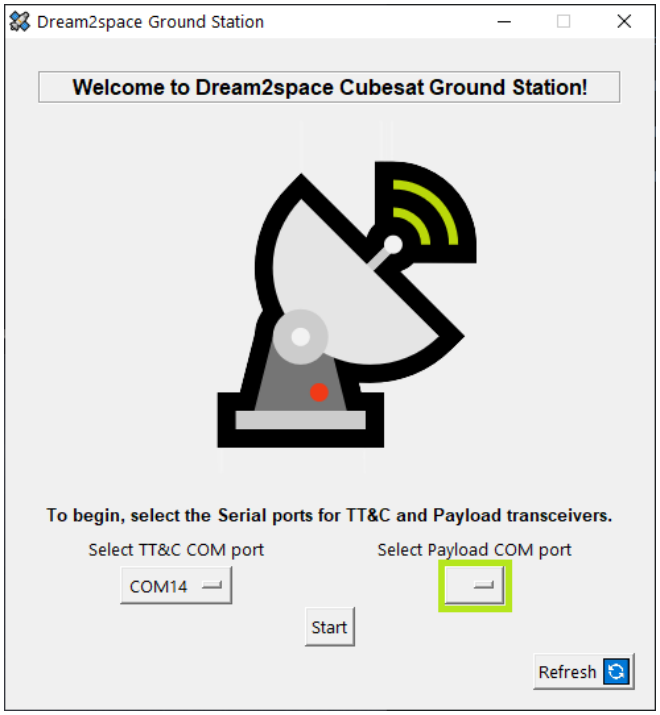


Select the COM port that you have noted down after plugging in the TT&C transceiver's USB-UART bridge.

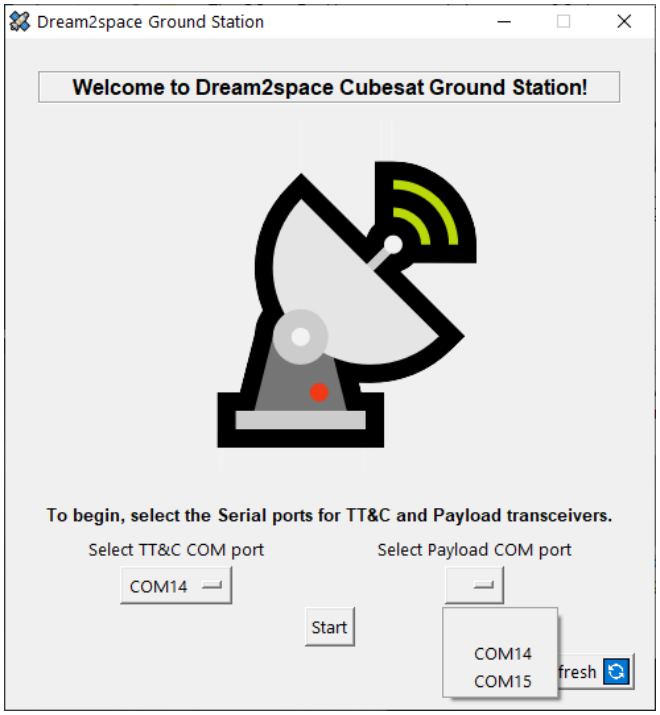
Step 2: Select the Payload COM port

To view the list of COM ports available for selection as the Payload transceiver's port, click on the dropdown menu.

The dropdown menu is boxed in **green** in the screenshot below.



The list of discovered COM ports will be displayed.

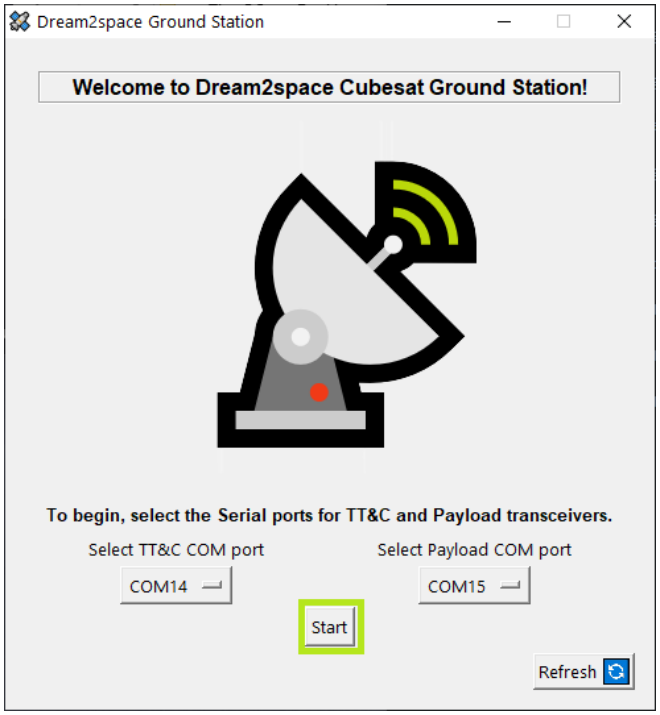


Select the COM port that you have noted down after plugging in the Payload transceiver's USB-UART bridge.

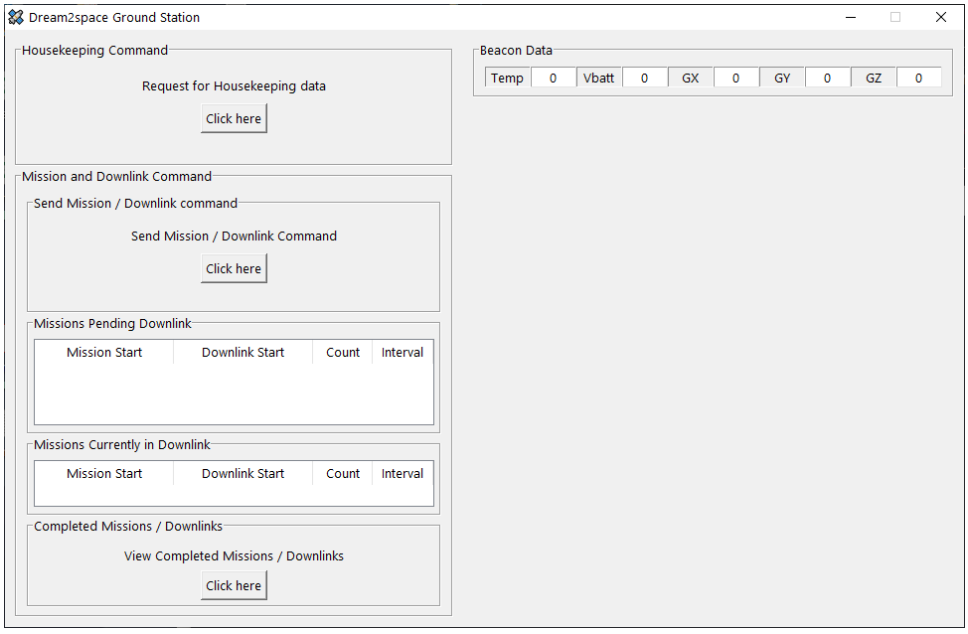
Step 3: Confirm and Start running app

After selecting COM ports for the TT&C and Payload transceivers, click on the Start button to proceed.

The Start button is boxed in **green** in the screenshot below.



After which, the app will display the Ground Station main page as shown below.

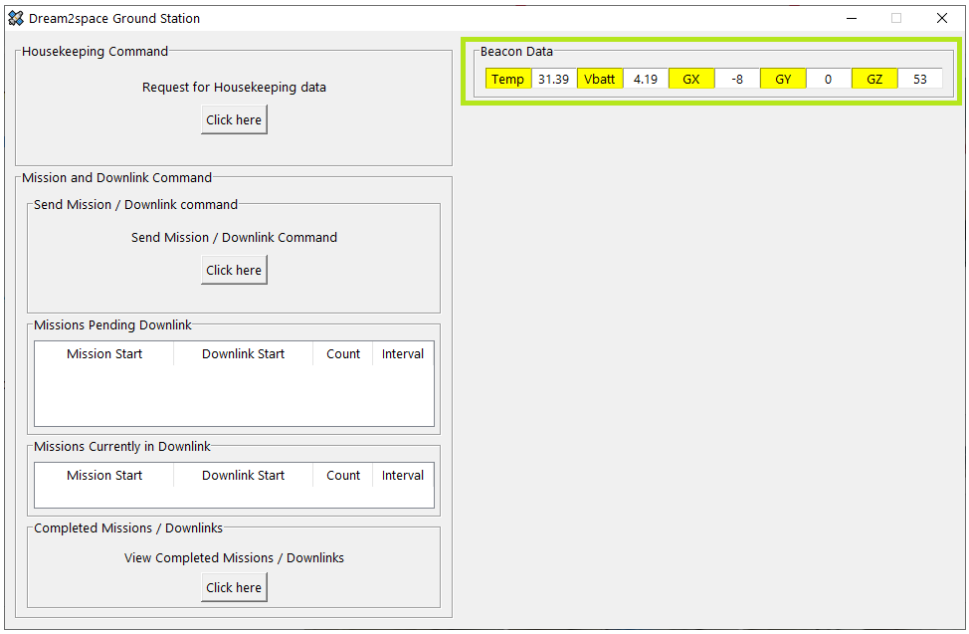


Ground Station Beacon Panel

Every minute, the Dream2space Cubesat will send beacons to advertise its presence.

The Ground Station will pick up the beacons to display it in the Beacon panel of the Ground Station.

The Beacon panel is boxed in **green** in the screenshot below.



The Beacon panel display will blink in **yellow** to indicate a new beacon has arrived in the Ground Station.

Ground Station Housekeeping Data Panel

The Ground Station is capable of sending commands to the Dream2space Cubesat to retrieve housekeeping data stored onboard.

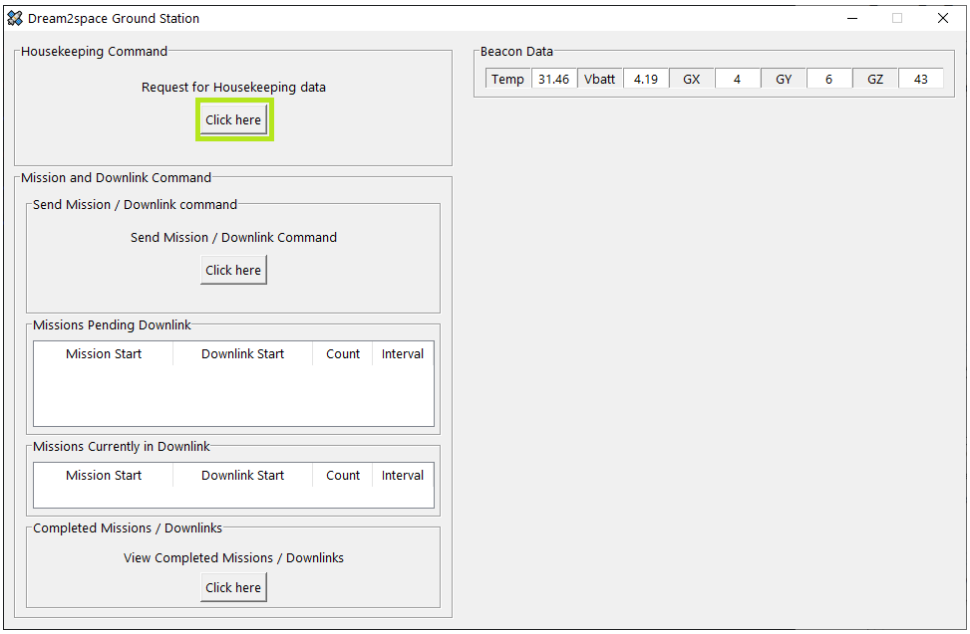
Housekeeping data refers to sensor data collected by the On-board Computer (OBC).

The steps below show how to retrieve housekeeping data from the Dream2space Cubesat.

Step 1: Send the Housekeeping Command

To send a housekeeping command, click on the button to request for housekeeping data.

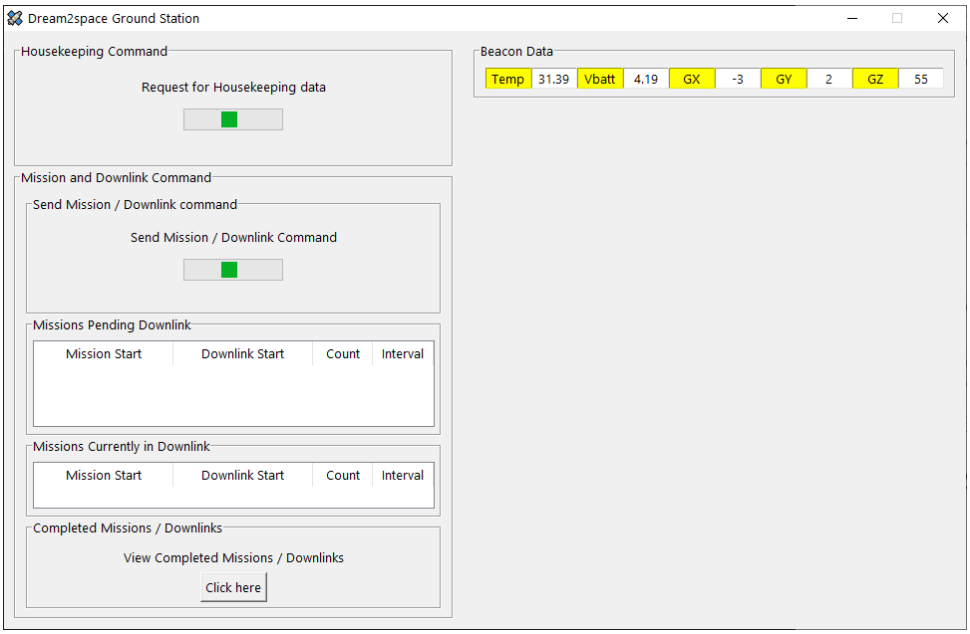
The button is boxed in **green** in the screenshot below.



After the Housekeeping command request button is clicked, the housekeeping command will be sent to the Dream2space Cubesat.

While the command is being sent, the progress bar will be shown.

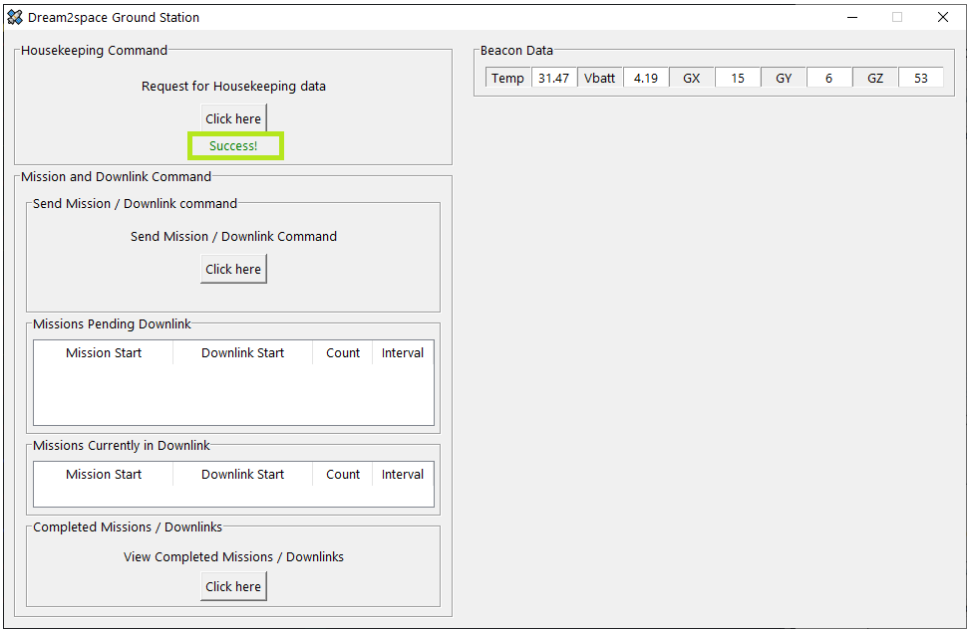
To ensure that the housekeeping command is sent without disruption, all commands sending will be disabled.



Once the Ground Station receives a response from the Dream2space Cubesat **successfully** (after approximately 5 seconds), the Housekeeping Data panel will indicate with a success message.

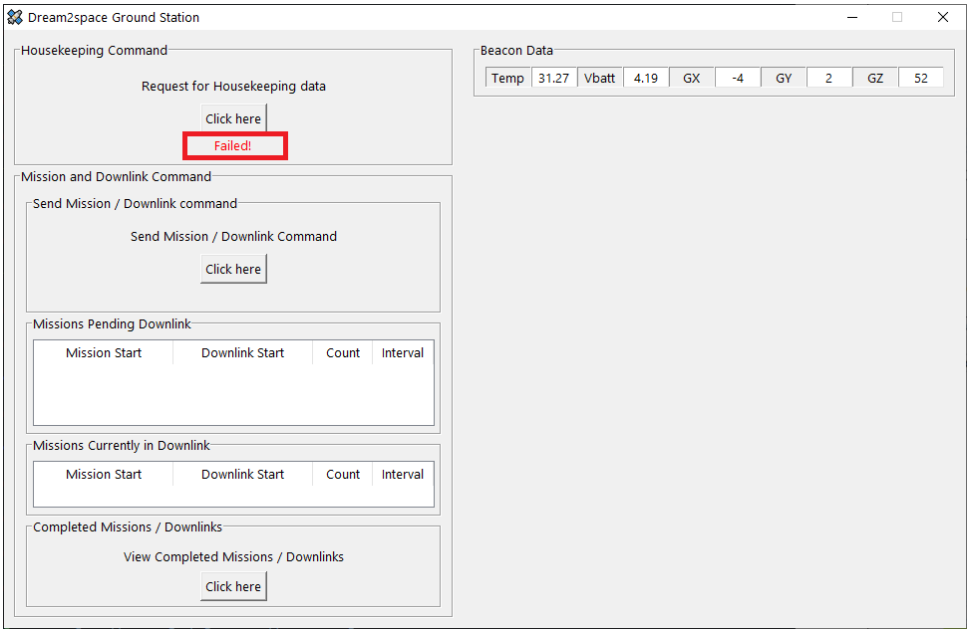
Upon seeing the success message, proceed to Step 2.

The success message is boxed in **green** in the screenshot below.



If the progress bar still appears after 10 seconds, the operation is likely to have failed and an error message will be shown.

The error message is boxed in **red** in the screenshot below.



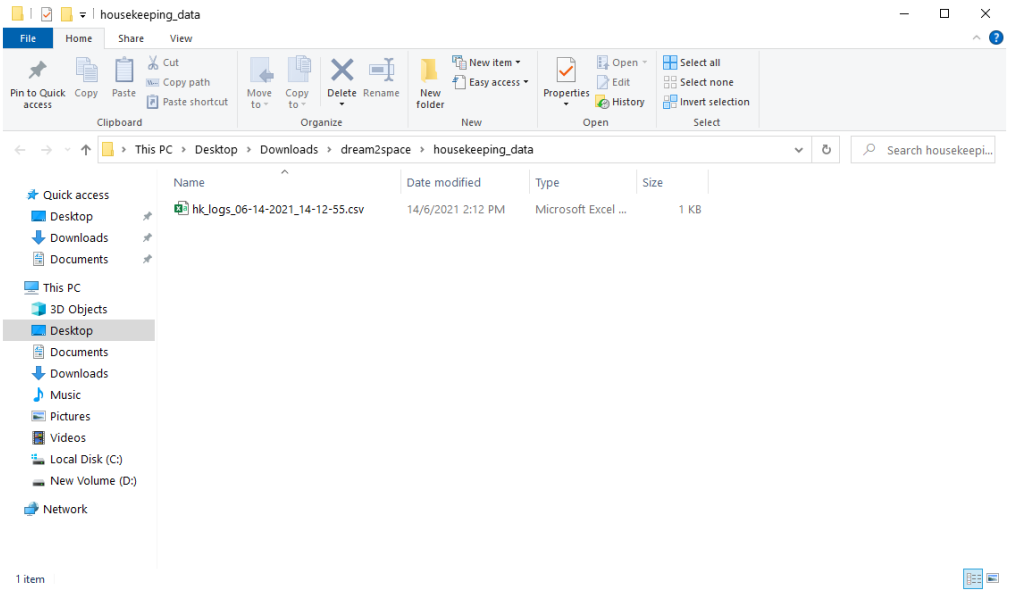
To retrieve housekeeping data, send the housekeeping command as described in Step 1.

Step 2: Navigate to location where logs are saved

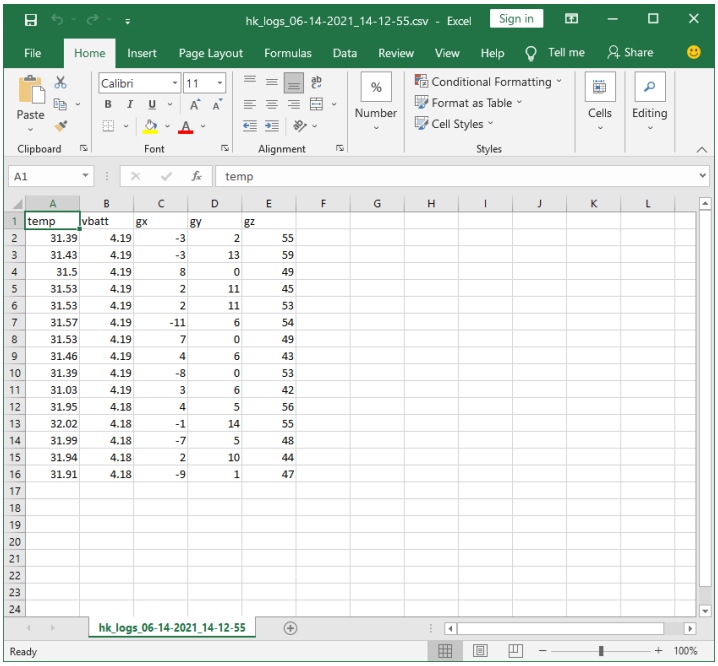
After the response containing housekeeping data is successfully received by the Ground Station, the Ground Station will process, save into Comma Separated Values (CSV) log files and pop up the Explorer window showing the folder containing the CSV file.

The CSV file is saved in the dream2space/housekeeping_data folder.

For instance, the screenshot below shows the Explorer window popped up after a successful housekeeping data retrieval operation.



Click on the CSV file and the CSV file will contain the housekeeping data received, as shown in the screenshot below.



Ground Station Mission Panel

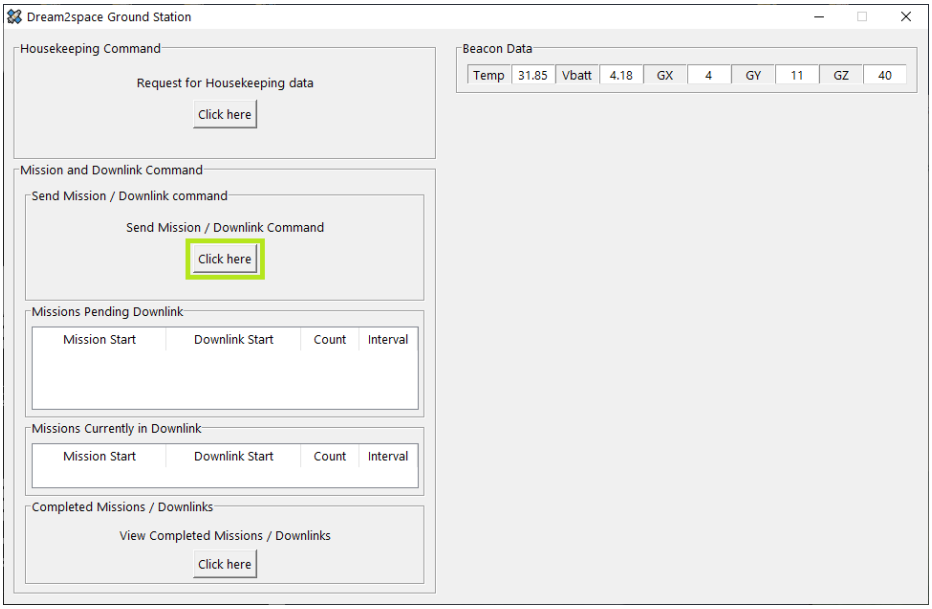
The Ground Station is capable of sending Mission commands to the Dream2space Cubesat to capture images and transmitting them down to the Ground Station for storage.

The steps below show how to send a Mission command and receive images via downlink from the Dream2space Cubesat.

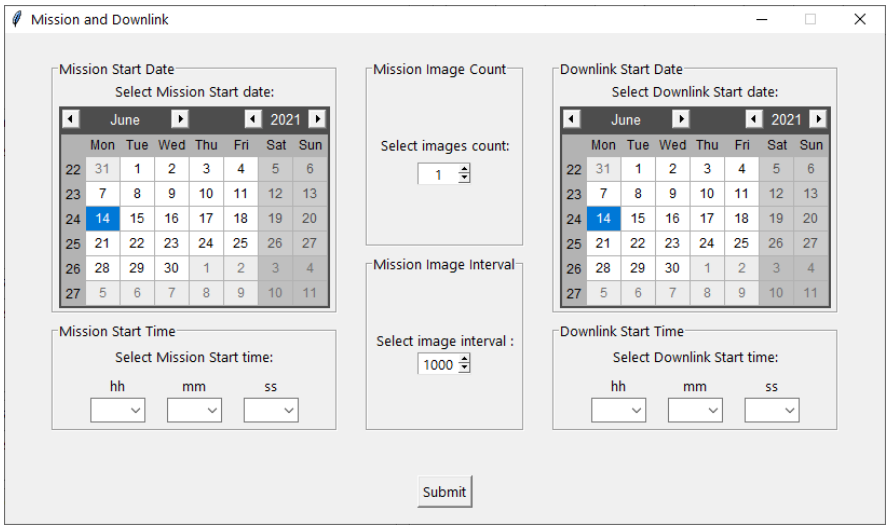
Step 1: Open Mission Command window

Click on the button to send a Mission/Downlink command.

The button is boxed in **green** in the screenshot below.



A Mission command window will pop up, as shown in the screenshot below.



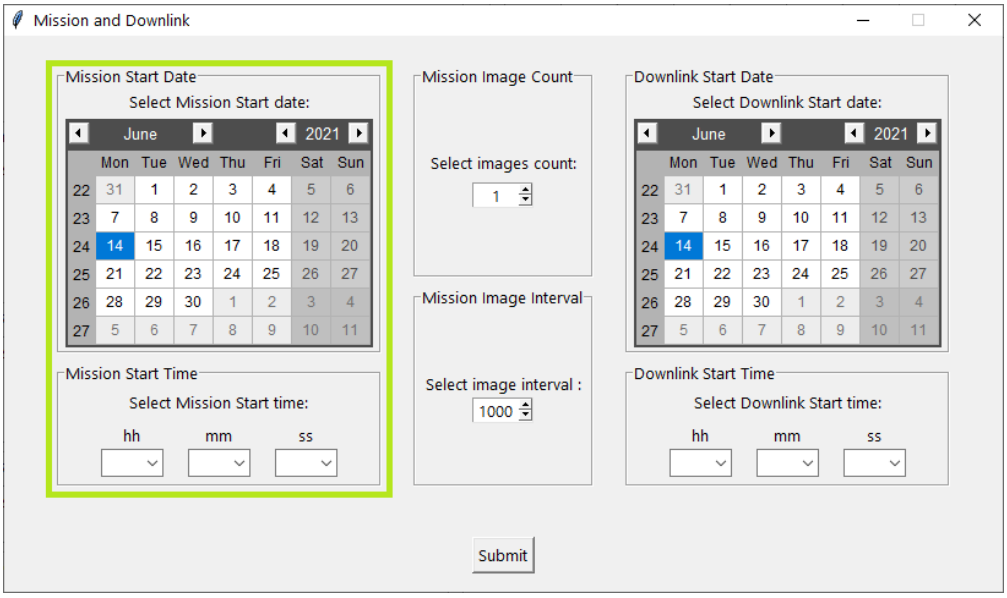
Step 2: Fill in Mission Start date and time

Fill in the Mission Start date and time in the Mission Start Date and Mission Start Time panels.

There are some rules that the Mission Start date and time needs to adhere to:

1. The Mission Start date and time must be in the future.
2. It is recommended to be at least 2 minutes from the current time.
3. The Mission Start time must not be less than 15 seconds before or after an already scheduled Mission.
4. There can only be at most 3 incomplete missions at any time.

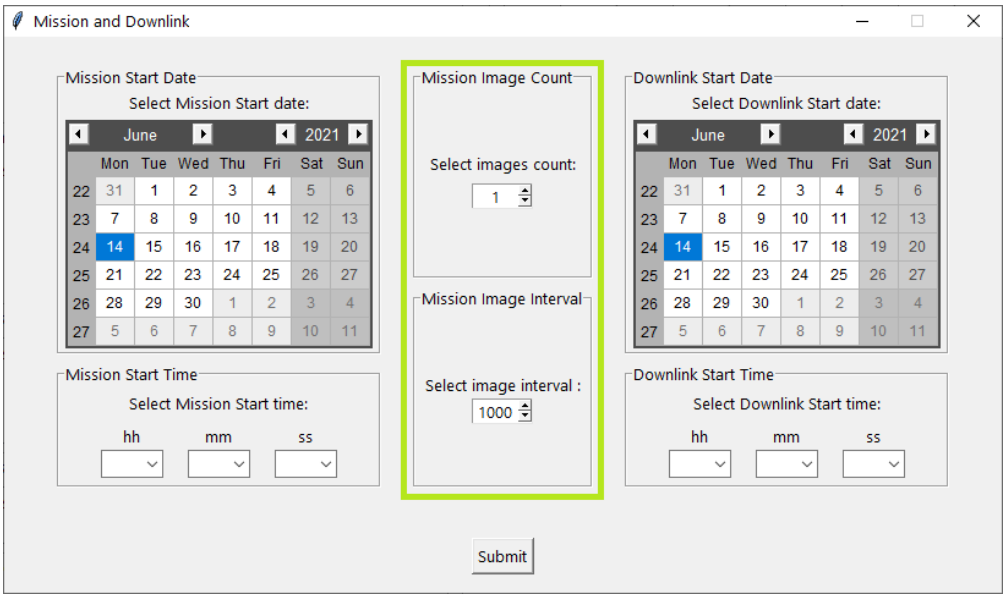
The Mission Start Date and Mission Start Time panels are boxed in **green** in the screenshot below.



Step 3: Fill in Mission images and interval

Fill in the number of images to be taken in the mission in the Mission Image Count panel and the interval between each image in the Mission Image Interval panel.

The Mission Image Count and Mission Image Interval panels are boxed in **green** in the screenshot below.



In each field, there are some allowed values that these mission parameters can take.

Use the arrows to select the values to input for each mission parameter.

The table below shows the values allowed for the Mission Image Count and the Mission Image Interval field.

Field	Units	Min	Max
Mission Image Count	N/A	1	3
Mission Image Interval	ms	1000	5000

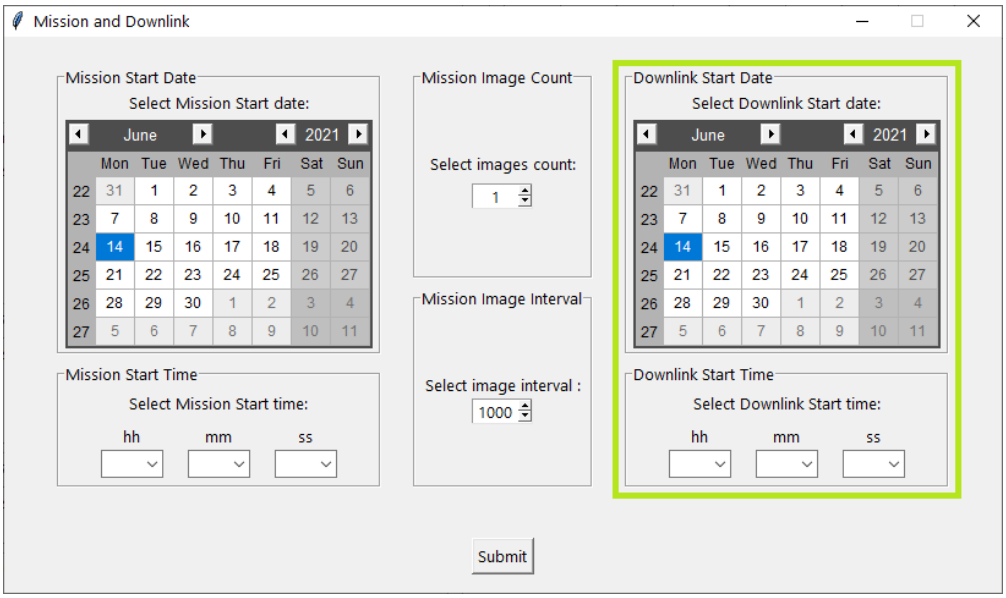
Step 4: Fill in Downlink Start date and time

Fill in the Downlink Start date and time in the Downlink Start Date and Downlink Start Time panels.

There are some rules that the Downlink Start date and time needs to adhere to:

1. The Downlink Start date and time must be in the future.
2. The Downlink Start date and time must be after the Mission Start date and time.
3. The Downlink Start date and time must not be less than 10 minutes before or after an already scheduled Downlink.

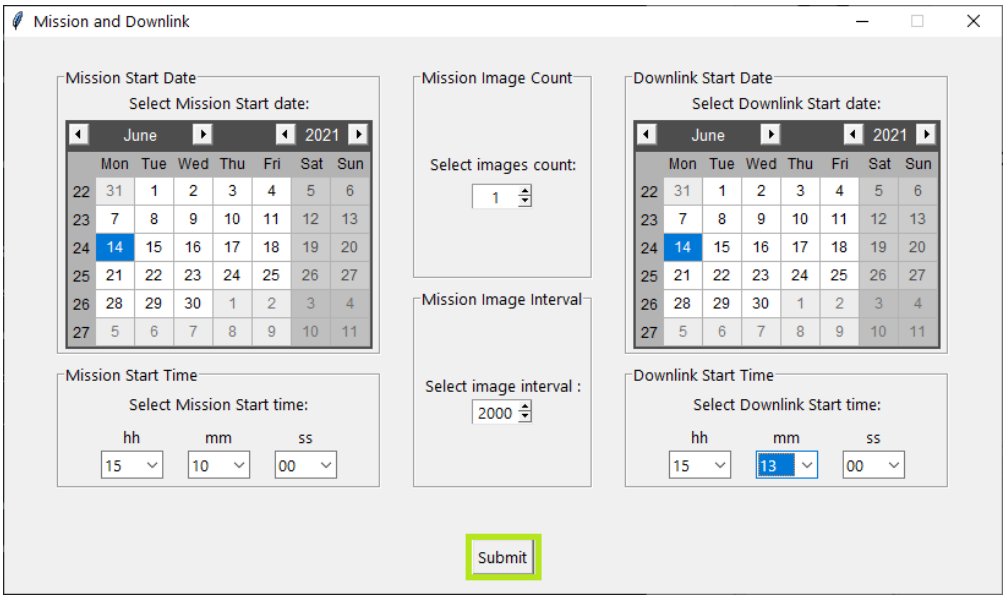
The Downlink Start Date and Downlink Start Time panels are boxed in **green** in the screenshot below.



Step 5: Send the Mission command

To send the mission command, click on the Submit button.

The Submit button is boxed in **green** in the screenshot below.

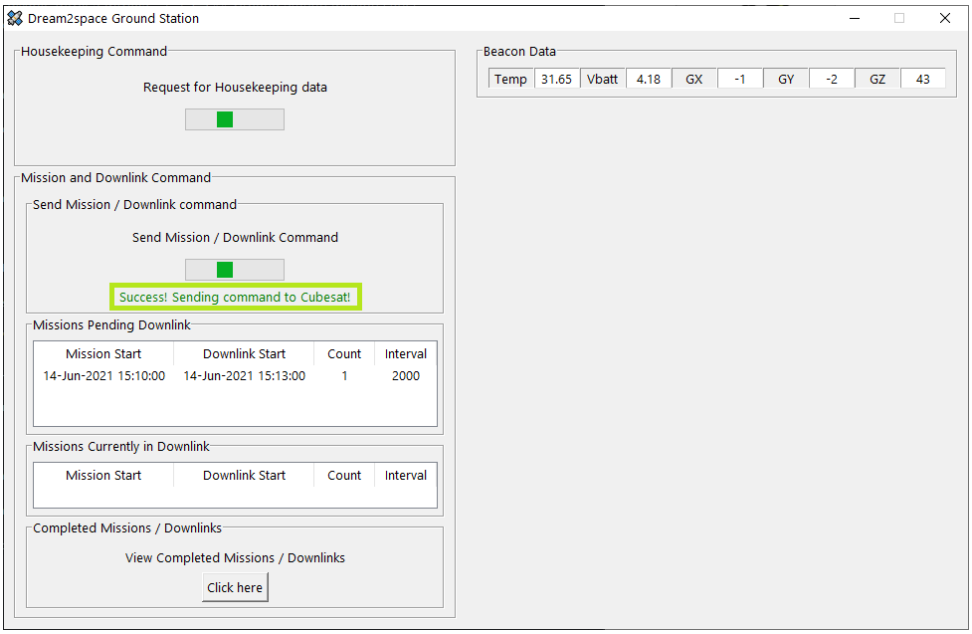


Step 6: Waiting for Mission to be executed

After the Submit button is clicked, the command will be sent to the Dream2space Cubesat.

While the command is being sent, the progress bar will be shown.

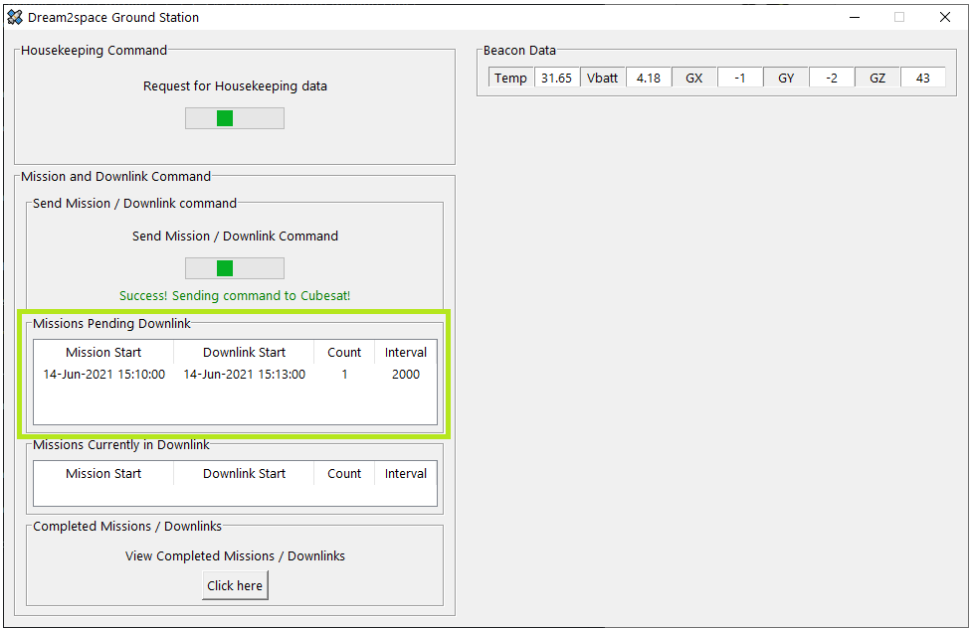
To ensure that the housekeeping command is sent without disruption, all commands sending will be disabled.



After the mission command is sent, a mission record is kept in the Missions Pending Downlink panel.

The record will be stored here until 2 minutes before the Downlink time of the Mission.

An example of a mission record in the Missions Pending Downlink panel is boxed in **green** in the screenshot below.

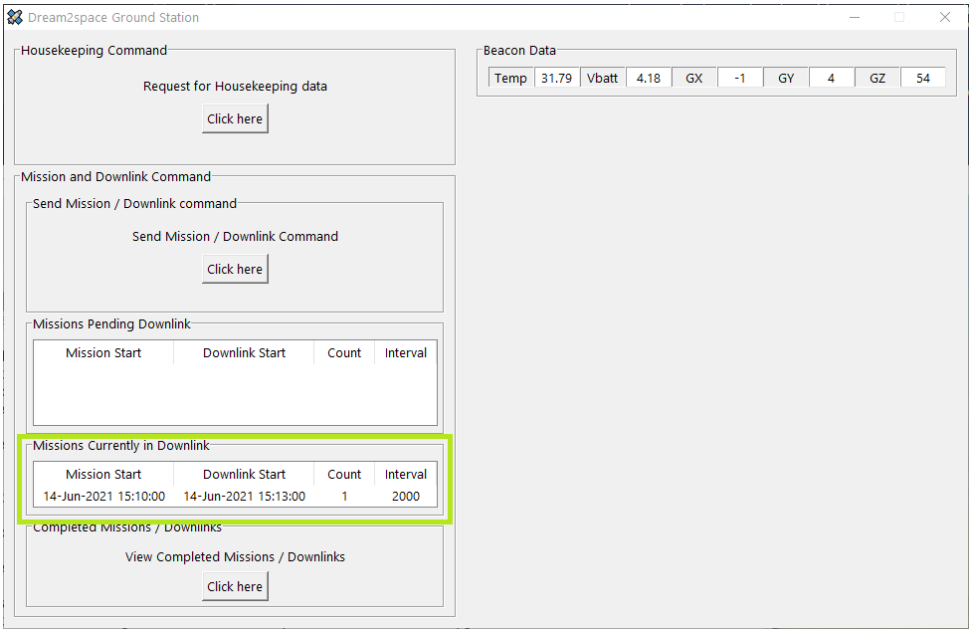


Step 7: Waiting for Downlink to be completed

When a mission is 2 minutes away from its Downlink time, the Ground Station will enter standby mode to wait for the downlink of images.

When this happens, the mission record will be shifted from the Missions Pending Downlink panel to the Missions Currently in Downlink panel.

An example of a mission record in the Missions Currently in Downlink panel is boxed in **green** in the screenshot below.



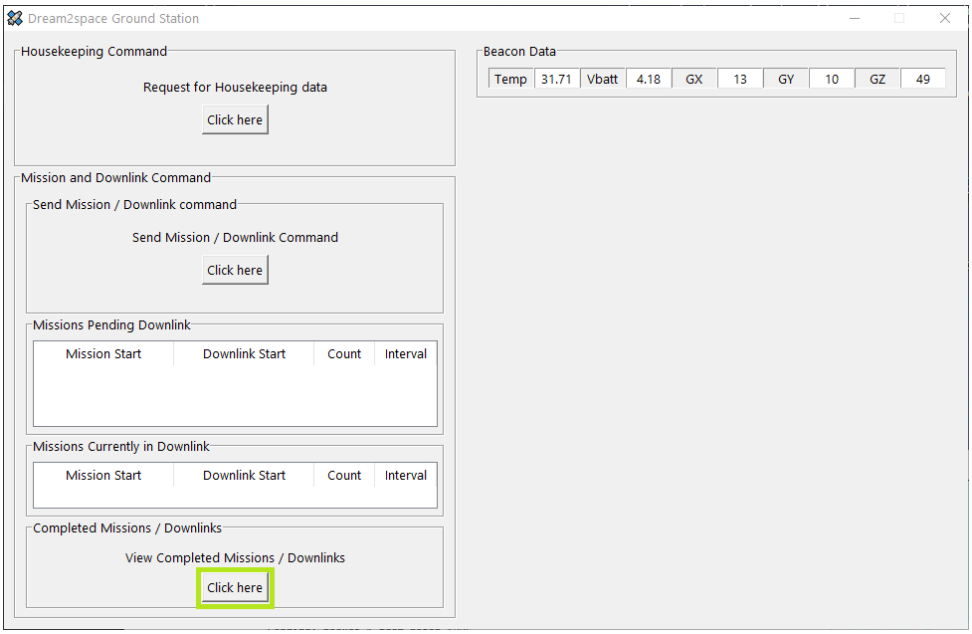
The mission record will remain there until the completion of downlink, error correction and decoding and of images collected (if successful).

Step 8: Viewing status of Missions

After the completion of downlink, the mission record will be removed from the Missions Currently in Downlink panel.

To view the overall status of the mission, click on the button to view completed mission/downlink operations.

The button is boxed in **green** in the screenshot below.

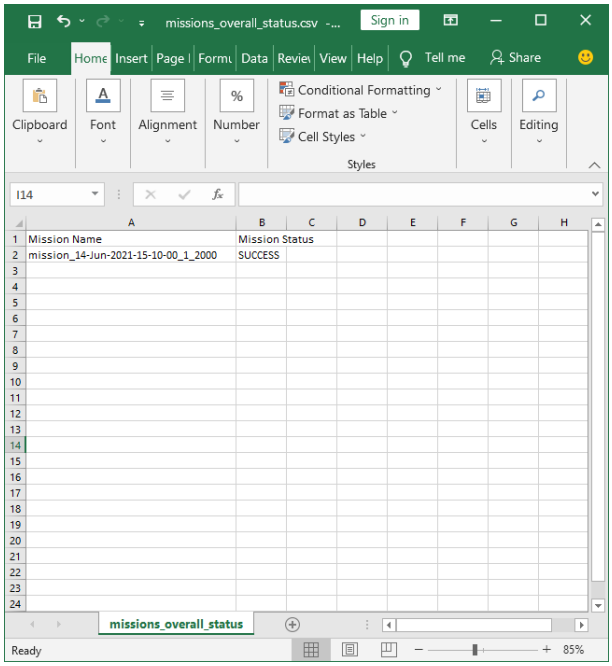


Clicking on the button opens up a CSV file containing the status records of all missions executed.

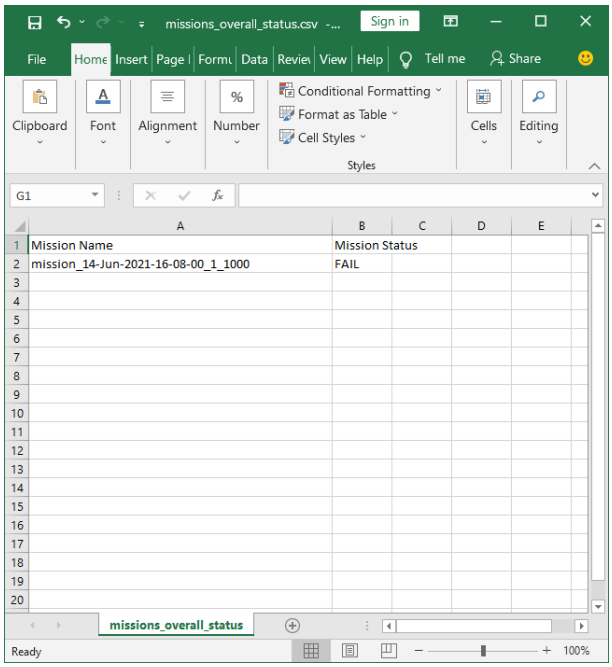
The table below describes what it means for an operation to be successful or have failed:

Status	Meaning
SUCCESS	All the process (Downlink, Error correction with Reed-Solomon, Decoding/Processing of images) are completed successfully.
FAILED	One of the above-mentioned processes have failed.

The screenshot below shows an example if the status if the mission was successful.



The screenshot below shows an example if the status if the mission has failed.

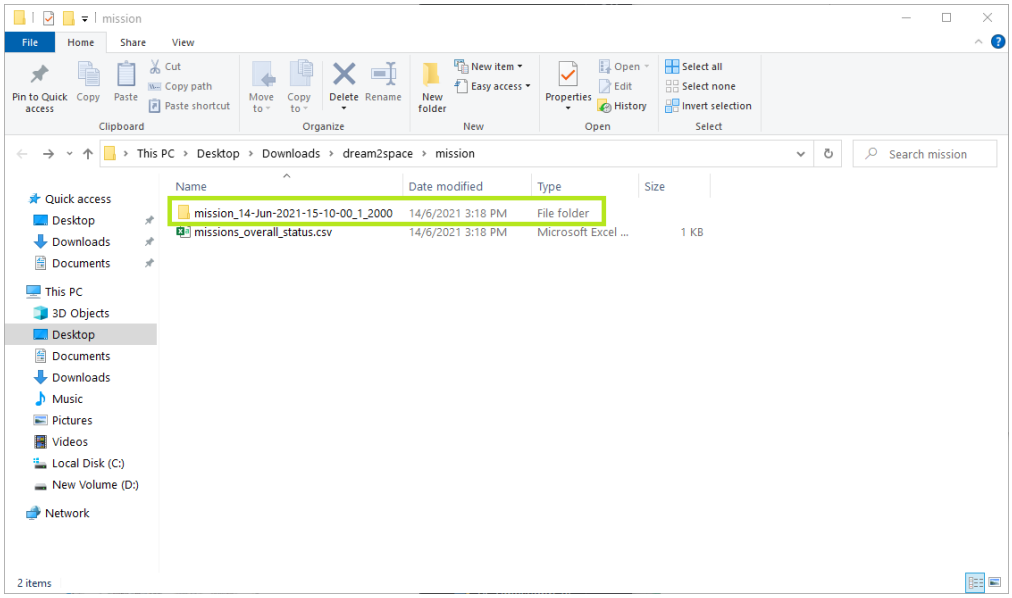


Step 9: Viewing Mission status and images

Clicking on the button also opens up an explorer to view the list of folders where mission images are stored in.

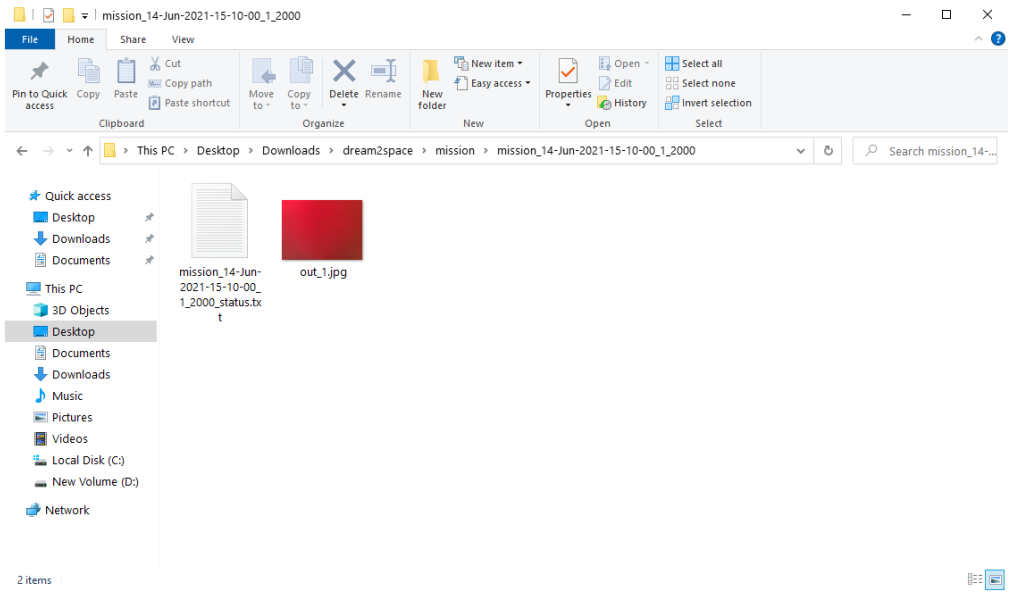
Click on the folder containing the executed mission to view the contents.

For example, the folder with the mission previously executed is boxed in **green** in the screenshot below.

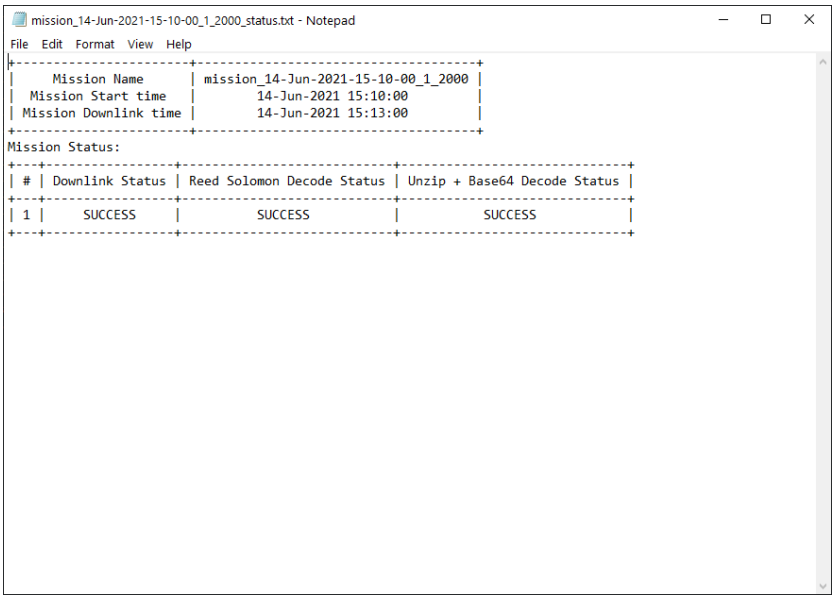


If the mission was successful, the recovered images will be found in the folder.

A text file log of the detailed mission status will also be found in the folder.

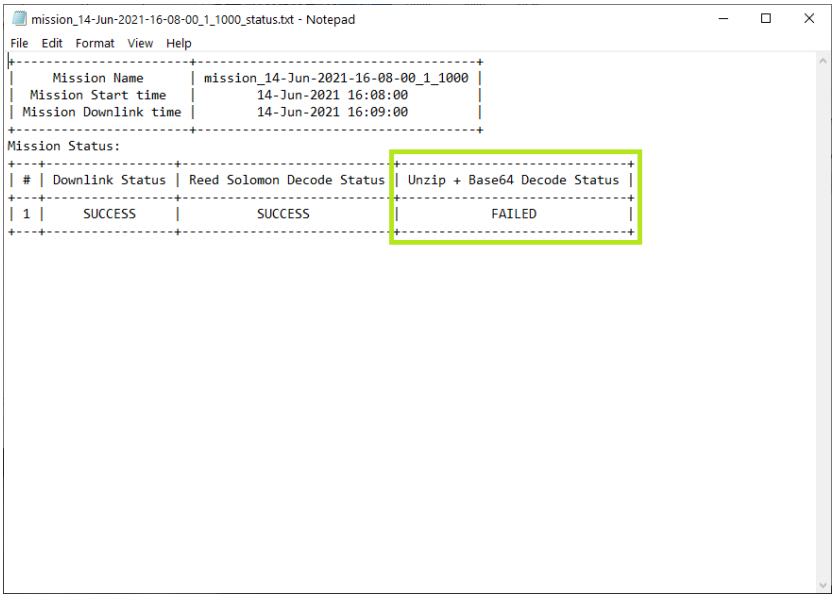


Opening the text log file will show the status of each process that the Ground Station undertakes to receive, perform error correction and decode the image.



This is important in the scenario to find out what is wrong in the downlink process.

For example, the logs below show that the decoding of the images using Base64 has failed.



This is useful for debugging and troubleshooting the connections and transmission between the Cubesat and the Ground Station.

Mass Properties Measurement Exercise

Items Required

Here is a list of items required for the mass properties measurement exercise.

Items	Remarks
Fully Assembled CubeSat	To be done following the instructions above
Measurement apparatus	Provided in lab
Stopwatch	For measurement of period of oscillation. Usage of a phone app is sufficient

Background Idea

Following the assembly and integration of a CubeSat, there are some pre-launch requirements to be fulfilled before they can be mounted into a launch vehicle. One of these requirements is related to its physical mass properties. For example, the mass of the CubeSat needs to be kept to no more than 1.33kg per unit. The CG needs to be within tight tolerances from the Centroid and the Mass Moment of Inertia needs to be within a specified range for launch and control stability.

This exercise aims to have the CubeSat meet a certain set of requirements for Weight, Centre of Gravity and Moment of Inertia.

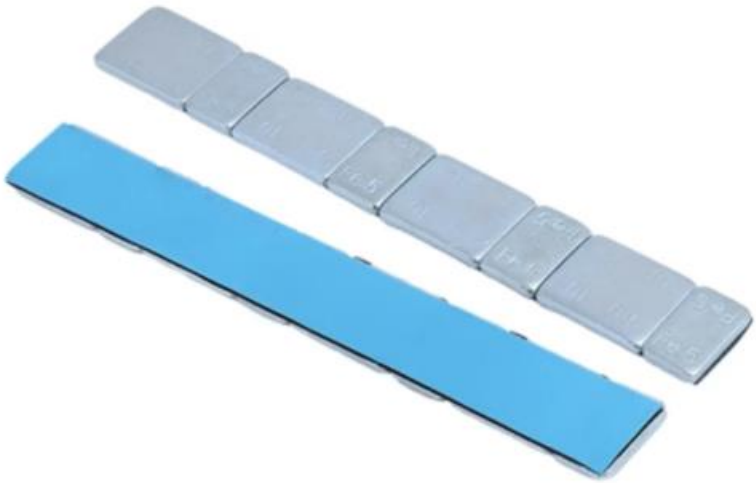
Each group will submit the CubeSat to the Instructor to take measurement of the mass property, as shown in the picture below. The equipment will be set up in the NUS Lab.

Step 1: Weight and Centre of Gravity (CG) Measurement (15 mins)

1. The weights at 3 specific points on the CubeSat will be taken. This will enable 2 sets of CG values to be calculated.
2. The CubeSat will then be rotated 90 degree and the weights at another 3 specific points taken.
3. The measurements at step 1 and 2 will enable the CG (X, Y and Z direction) of the CubeSat to be calculated. These values will be given to the project group.

Step 2: Weight Balancing (1 hour)

1. Each group will be given 2 strips of ballasting weights as shown in the picture below. The strips, with adhesive on one side, consist of a combination of 5 grams and 10 grams units, with a total of 120 grams.

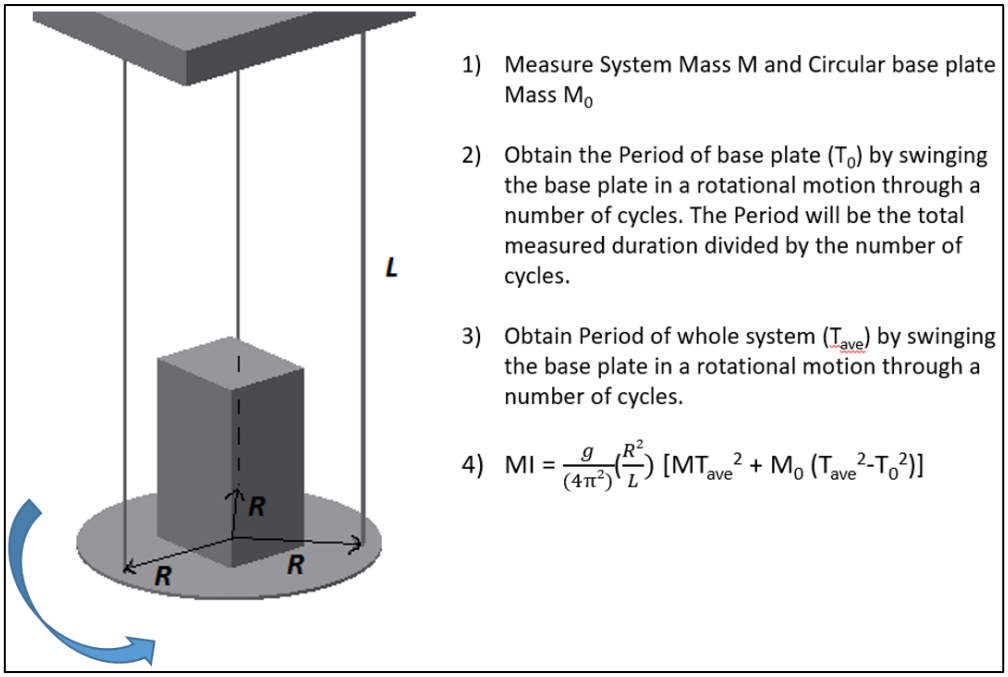


2. The group will analyse the measured CG values of the CubeSat, do calculations and decide how and where to position the ballasts on the CubeSat in order to bring the CG values as close to the Centroid as possible.

3. After mounting the ballasts, the group will submit the CubeSat to the Instructor to take a final measurement of Weight and CG values.

Step 3: Mass Moment of Inertia (MOI) Measurement (45 mins)

1. With the final known CG location of the CubeSat, the group will measure the MOI of one axis of the CubeSat, with the longer length of the CubeSat standing upright as shown in the figure below.
2. The group will use the Trifilar Pendulum method to do the measurement.



1) Measure System Mass M and Circular base plate Mass M_0

2) Obtain the Period of base plate (T_0) by swinging the base plate in a rotational motion through a number of cycles. The Period will be the total measured duration divided by the number of cycles.

3) Obtain Period of whole system (T_{ave}) by swinging the base plate in a rotational motion through a number of cycles.

4) $MI = \frac{g}{(4\pi^2)}\left(\frac{R^2}{L}\right)[MT_{ave}^2 + M_0(T_{ave}^2 - T_0^2)]$

3. Take note that to achieve an accurate result, the CG of the CubeSat must coincide with the axis of rotation

4. Discuss how you may be able to achieve an accurate measurement of the Period of Swing.

5. Each group is to submit their MI measurement result.

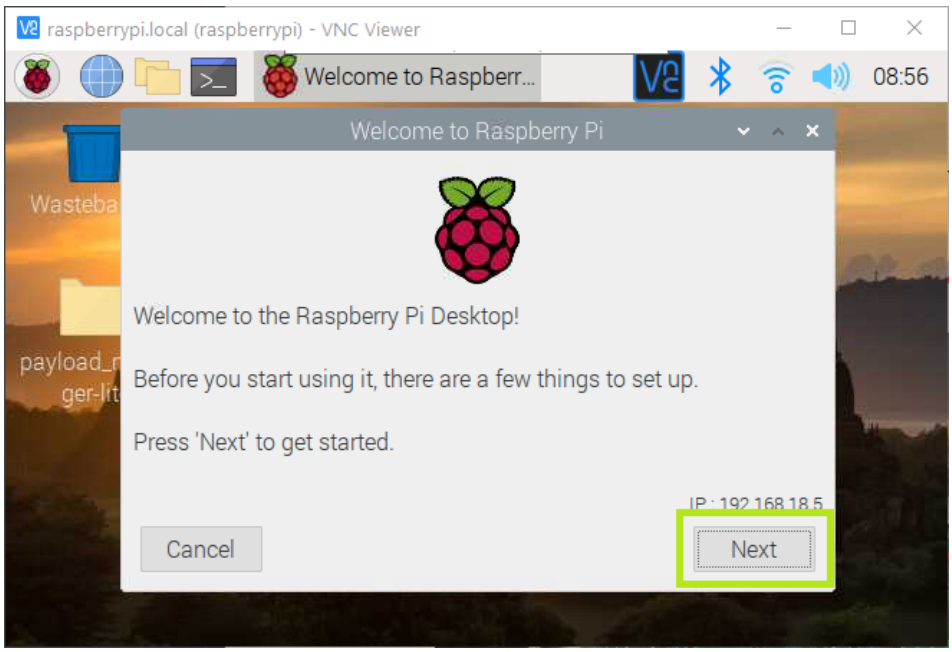
Appendix: Configure the GUI settings

The GUI settings of the Raspberry Pi will be configured.

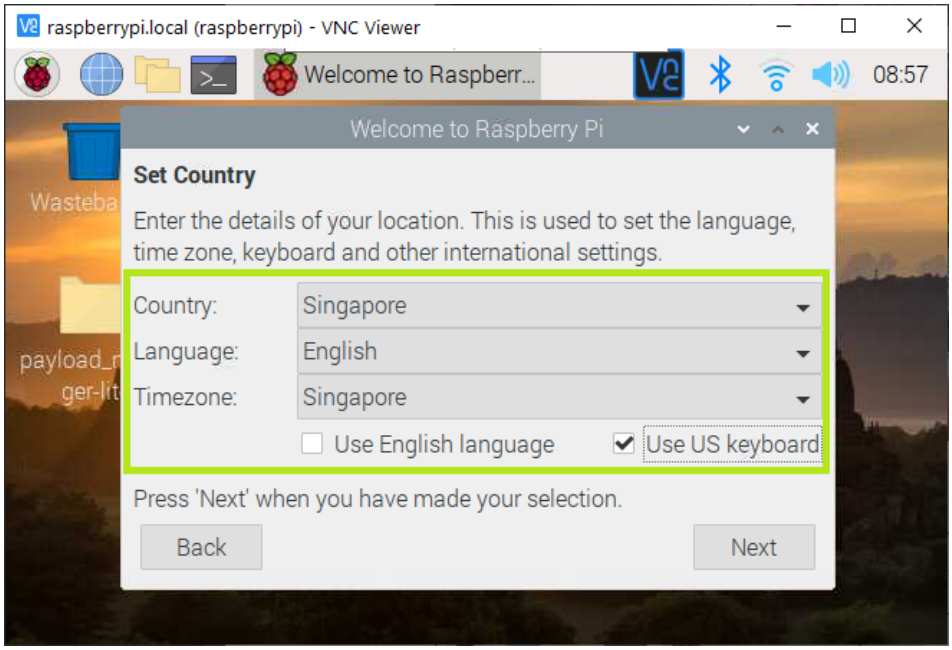
⚠ **Make sure that all the steps here are completed before powering off the Raspberry Pi.**

1. Click on the Next button to proceed with the setup.

   The Next button is boxed in **green** in the image below.

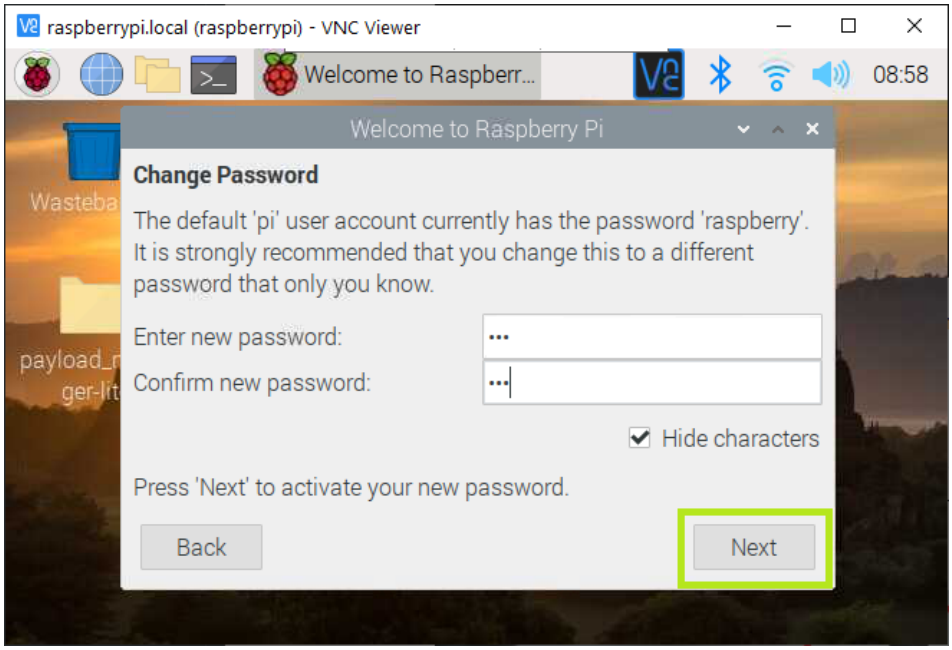


2. Select the Country, Language and Timezone.
    - Country: Singapore
    - Language: English
    - Timezone: Singapore



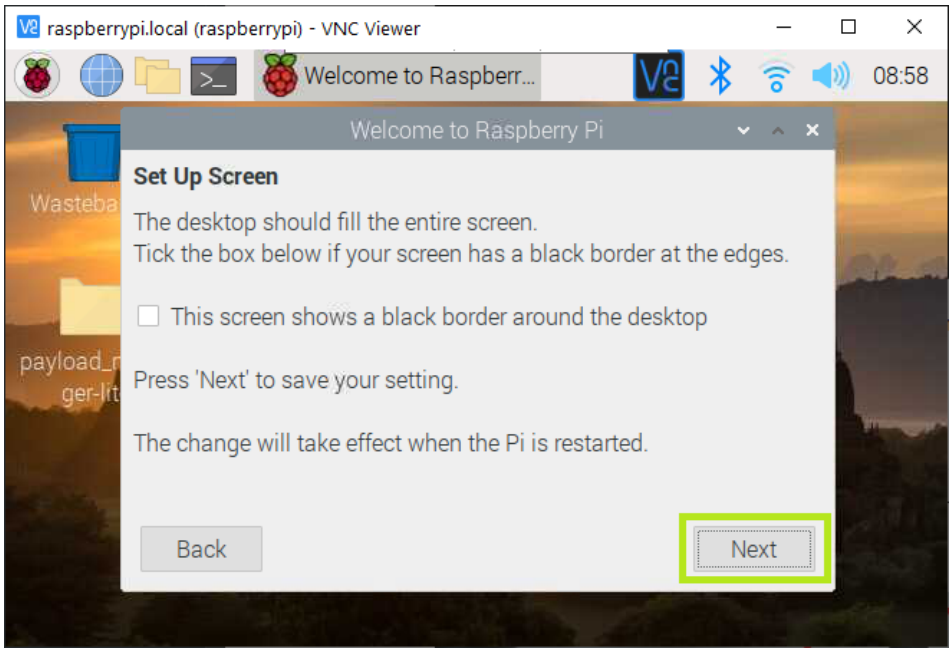
Click the Next button to proceed.

3. Configure the password for the Raspberry Pi OS.

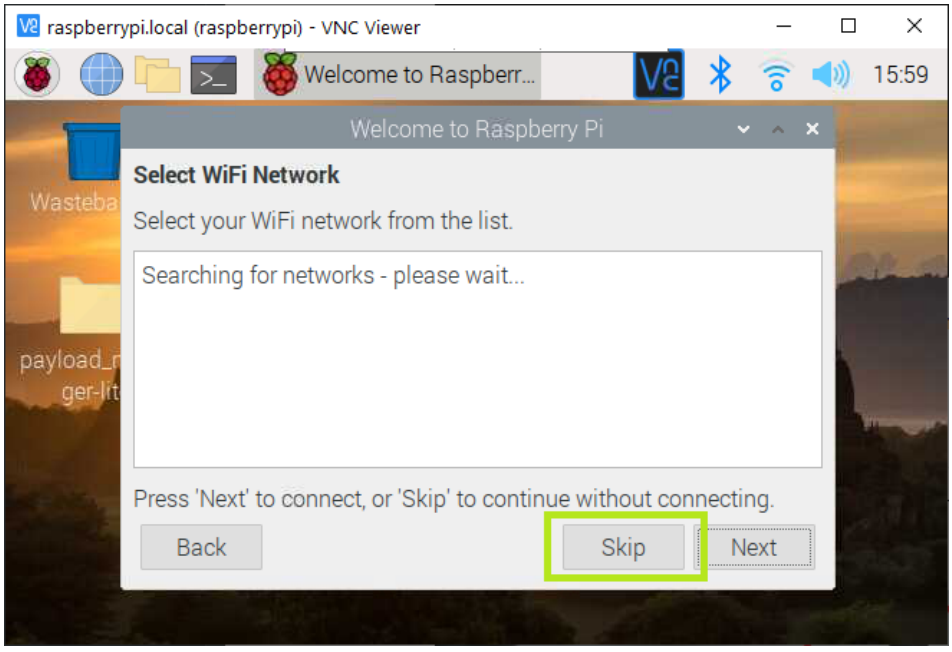


Click the Next button to proceed.

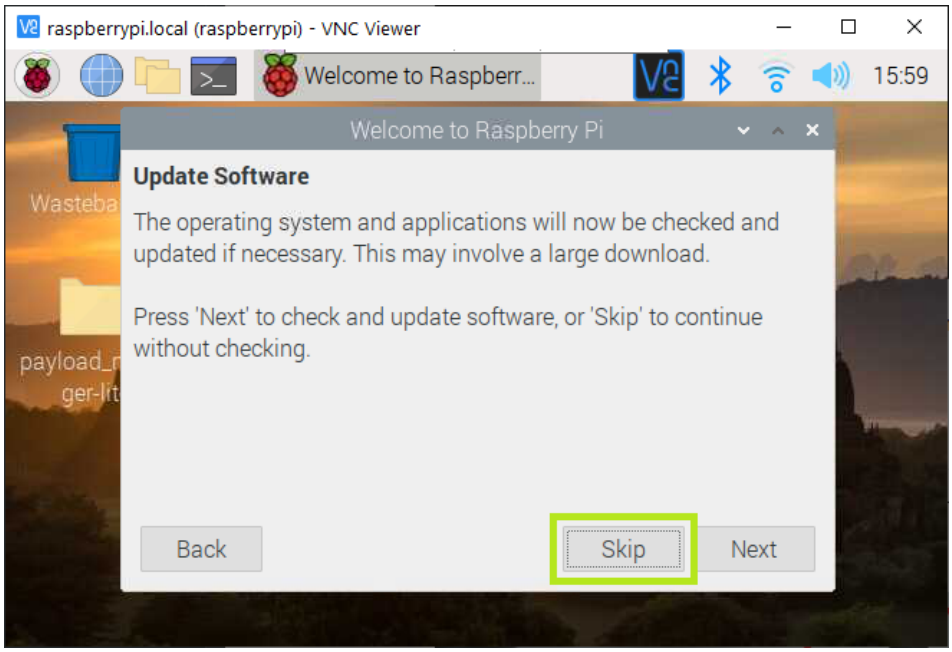
4. Click the Next button to skip setting the Screen configurations.



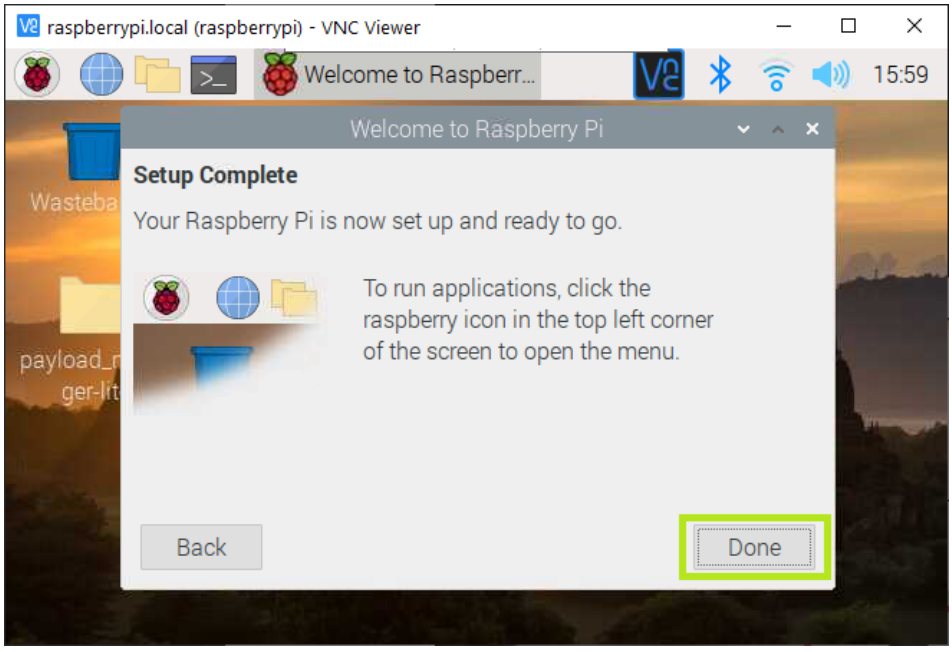
5. Click the Skip button to skip configuring the WiFi.



6. Click the Skip button to skip updating the OS.

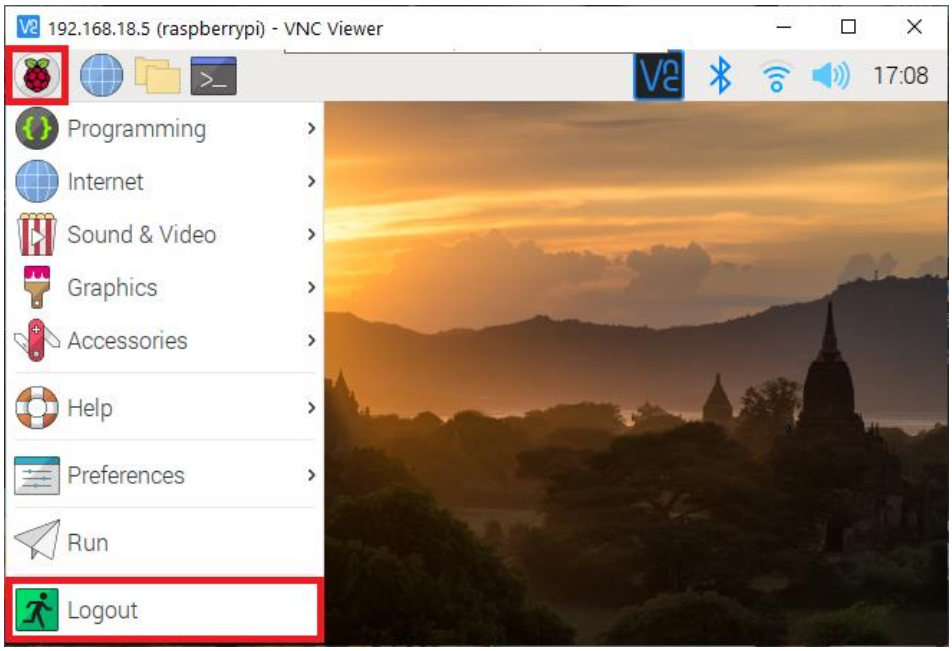


7. Click Done to complete setup.



8. Shutdown the Raspberry Pi.

   To navigate to the Shutdown menu, click on the Raspberry Pi Logo at the top left-hand corner and click the Logout button.



Select Shutdown to shut down the Raspberry Pi safely.