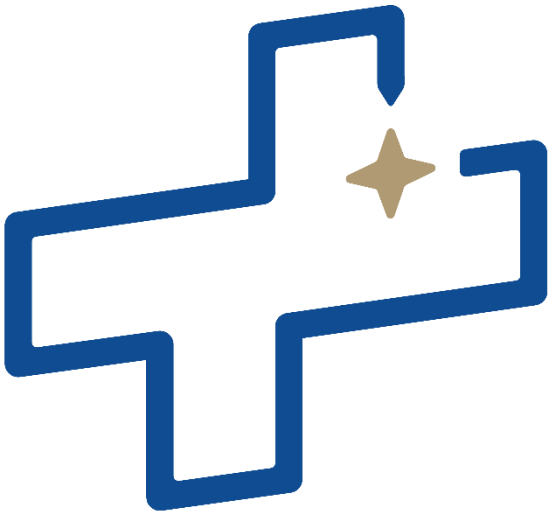

CUBESPACE

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Ver.A	AS	ALL	04/11/2022	First draft. Based on CT V4.2 User Manual V1.9.
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Reference Documents

[1] CS-DEV.REF.CT.M0.0E4.4-1 CubeStar Gen1 REF Ver.1.00 or later

[2] CS-DEV.ICD.CT.M0.0E4.4-01 CubeStar Gen1 ICD Ver.1.00 or later

List of Acronyms/Abbreviations

ESD	Electrostatic Discharge
FoV	Field of View
FPGA	Field-Programmable Gate Array
GUI	Graphical User Interface
GND	Ground
IC	Integrated Circuit
ICD	Interface Control Document
ICRS	International Celestial Reference System
I^2C	Inter-Integrated Circuit
JPL	Jet Propulsion Laboratory
MCU	Microcontroller Unit
MEMS	Microelectromechanical System
OBC	Onboard Computer
PCB	Printed Circuit Board
QUEST	Quaternion Estimator
SPI	Serial Peripheral Interface
TCMD	Telecommand
TLM	Telemetry
UART	Universal Asynchronous Receiver/Transmitter
V	Volt
s	seconds
ms	milliseconds
µs	microseconds

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1. Introduction

This document will guide the user through the steps to connect CubeStar, as shown in Figure 1, to a PC. Once a connection is established, a CubeSupport application can be used to interface with CubeStar. A health check must be performed to confirm that CubeStar is working as intended. The steps to perform the health check are explained in Appendix A (chapter 4). After each health check step in chapter 4, a table is provided where the measured results must be filled in and the expected results are shown. The results must be completed and sent back to CubeSpace within 3 months after receiving the CubeStar to acknowledge that the CubeStar was received in working order.

Figure 1 – CubeStar V4.4

CubeSpace is continually innovating on designs and device capabilities. Since the firmware for CubeStar is always improving, CubeSpace will release updated software from time to time. This document therefore also explains how to flash such an update to CubeStar.

Please note that this document is distributed with copies of the *CubeStar Reference Manual* [1] and *CubeStar Interface Control Document* [2], these documents contain all information regarding the lower-level software and hardware interfaces.

Table 1 – CubeStar Subject Version

Element	Version
Hardware Version	V4.4
Firmware Version	3.9
Interface Version	5

Always take the necessary precautions for ESD protection when handling CubeStar. Always handle CubeStar in a clean area or cleanroom. Extra care must be taken to keep the lens clean.

Before handling, please note that CubeStar is highly sensitive. If the lens is moved or turned in the lens holder, the pre-programmed calibration values will no longer be valid, and CubeStar will no longer function correctly. Even a slight shift in lens position will affect the performance of CubeStar. It is also essential to design mounting supports for the lens in the satellite to prevent the lens from shifting due to launch vibrations

2. Interfacing with CubeStar

This chapter describes how to interface with CubeStar via a computer running Windows by connecting CubeStar to a CubeSupport PCB and the CubeSupport application. This section is only applicable to clients who bought CubeStar as a standalone unit.

2.1 Hardware interface

Figure 2 shows the CubeStar, a CubeSupport PCB and an interface harness that are included in the delivered package. As standard, a 3-pin USB Serial to UART cable with a DC power cable, as shown in Figure 4, is provided. Upon request, a 4-pin USB Serial to UART cable, as shown in Figure 3, can be provided as alternative. Lastly, a USB flash drive will also be included that contains all required documentation and the CubeSupport application.

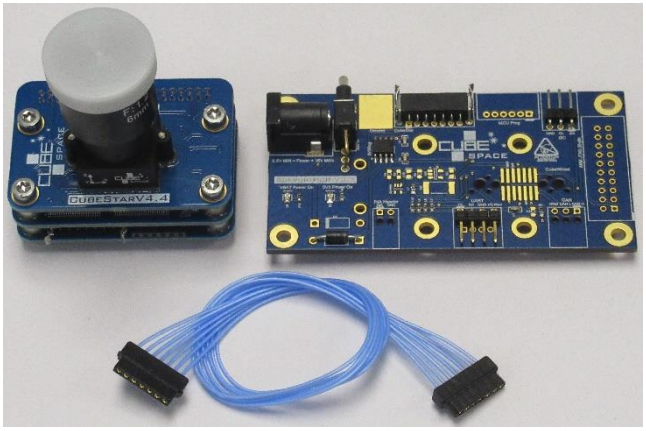

Figure 2 – CubeStar, CubeSupport PCB and interface harness

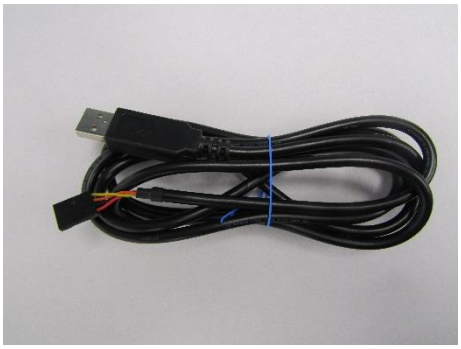

Figure 3 – 4-pin USB Serial to UART Cable

Figure 4 – 3-pin USB Serial to UART Cable with DC power cable

In the case of a 4-pin UART cable, connect it to the CubeSupport PCB ensuring the red wire (VCC) is connected to the *PC Pow* pin on the *UART* header, as shown in Figure 5 below.

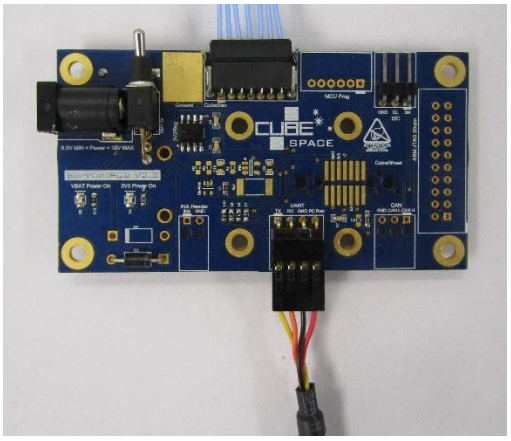

Figure 5 – 4-pin USB Serial to UART Cable Connection

In the case of a 3-pin UART cable, connect it to the CubeSupport PCB ensuring the yellow wire (UART Tx) is connected to the *Tx* pin on the *UART* header and connect the DC cable to the *Power* jack. These connections are shown in Figure 6. The DC cable must be connected to a DC power supply with a voltage range of 6.5V to 16V.

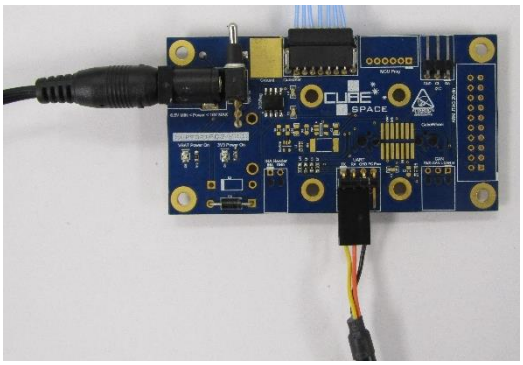

Figure 6 – 3-pin USB Serial to UART Cable and DC cable Connection

Always ensure that the UART cable is connected in the right orientation. Not complying with this specification can result in damaging the CubeStar electronics.

Plug the USB connector of the UART cable into the computer that will be used to interface with CubeStar. If the header on the 4-pin UART cable has been plugged in with the correct orientation, or the bench power supply is set to a voltage in the specified range and the *Vbat On* switch is in the up position, the *3V3 Power On* LED should light up, as shown in Figure 7.

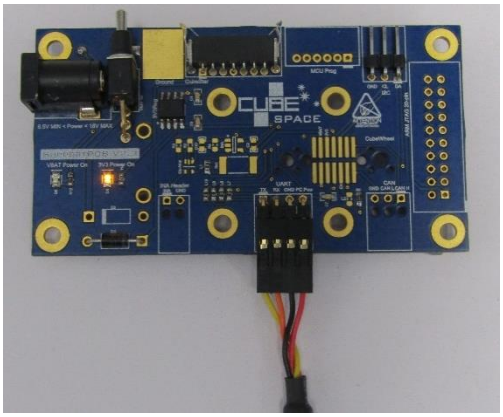

Figure 7 – Powered Up CubeSupport PCB

Now, disconnect the 4-pin UART cable from the USB port or switch off the power supply to ensure that the CubeSupport PCB has been powered down. Finally, attach the CubeStar interface harness to the CubeSupport PCB and CubeStar, and reattach the 4-pin UART cable to the interfacing computer or switch on the power supply. The final setup is shown in Figure 8 and Figure 9.

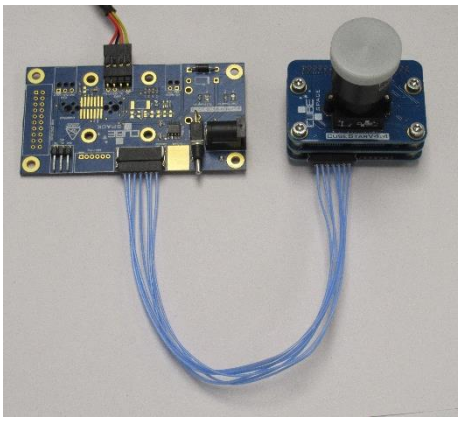

Figure 8 – Connected CubeStar with 4-pin UART cable

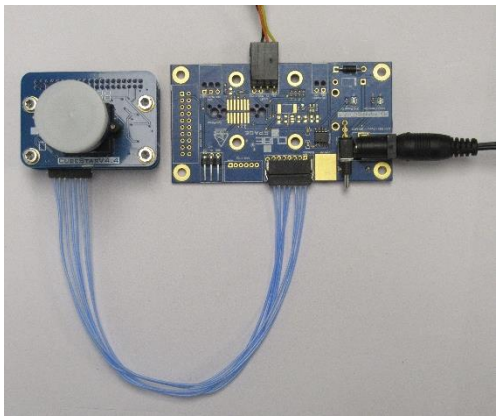

Figure 9 – Connected CubeStar with power cable

2.2 Com Port Setup

If a similar UART cable than the one provided have never been used on the PC, the drivers will need to be installed before connecting the UART cable. The drivers can be found at the link below and must be installed on the PC:

TTL-232R-3V3 FTDI UART Cable Drivers

The COM port should register on the PC once the UART cable is connected to the PC and the drivers have been installed. To check if the COM port is registered by the PC open the *Device Manager*. The USB serial port connection should show up under *Ports* as shown in Figure 10.

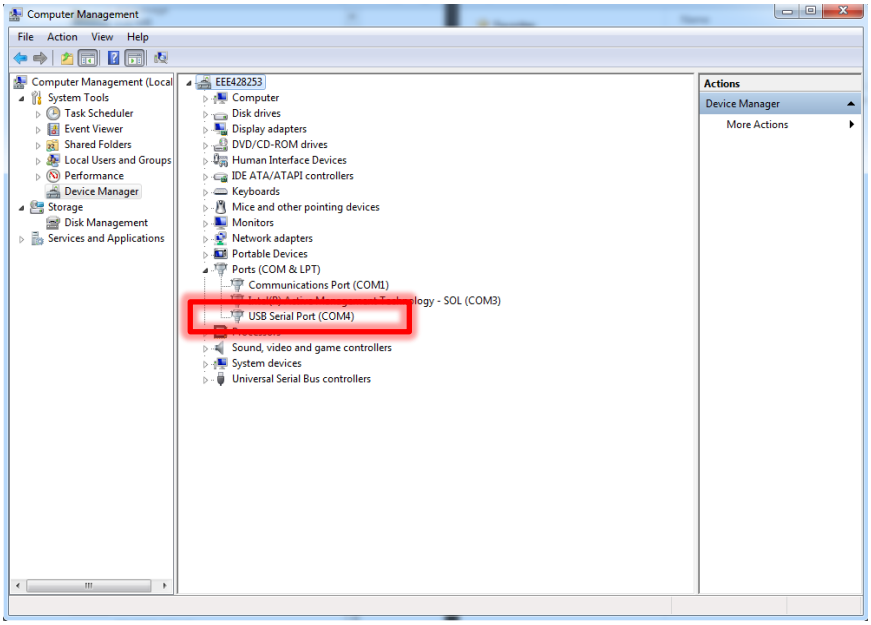

Figure 10 – Device Manager

In this case, the UART to serial cable is registered as COM4, but it can be different on other computers. Now the COM port connection can be configured. Follow these steps:

1. Right-click on the *USB serial port* and select the *Properties* option from the drop-down menu.
2. Select the *Port Settings* tab. The bits per second field does not need to be correct on this window. It will be correctly set when the connection is made to the COM port via the CubeSupport application.

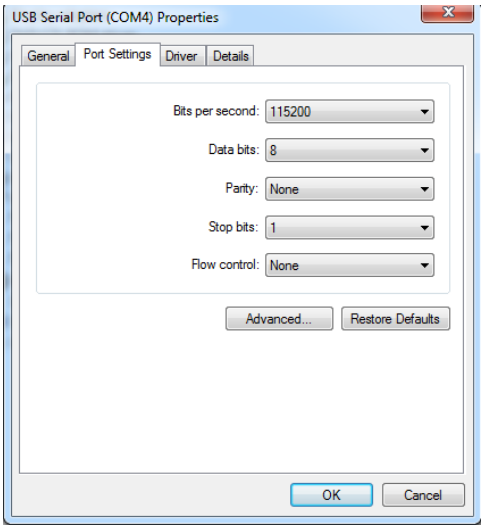

Figure 11 – USB serial port settings

3. Click the *Advanced…* button, which will open a new settings window.

4. Under the *BM Options* section set the *Latency Timer (msec):* field to 1 as shown in Figure 12.

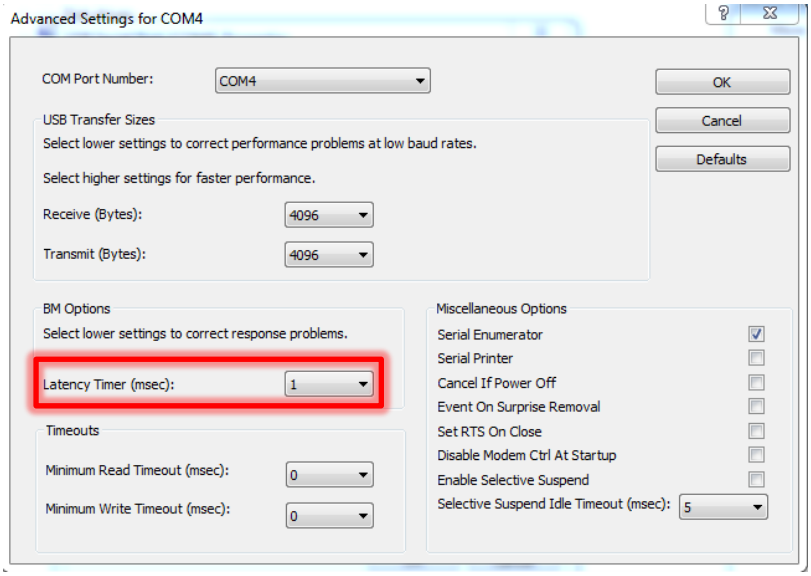

Figure 12 – USB serial port advanced settings

2.3 CubeSupport Application Interface

Once the steps in the previous section have been completed the CubeSupport application that can be found on the included USB drive can be used to connect to CubeStar. The CubeSupport application can be found as *cubesupport.exe* in the ZIP file *cubesupport v7.11.zip* located in the *Software* folder in the root of the USB drive.

Launch the *cubesupport.exe* file. The CubeSupport application will open a window as shown in Figure 13.

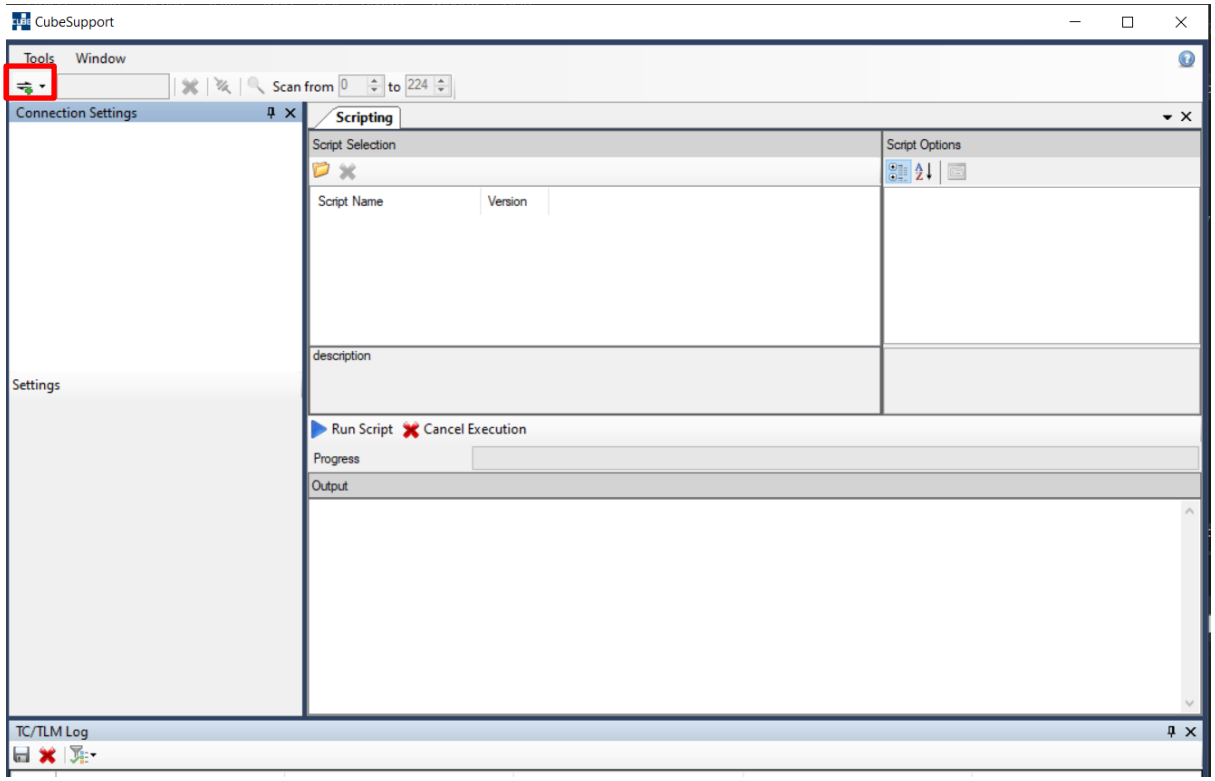

Figure 13 – Add a Connection to CubeSupport.

1. Click on the add connection icon ( ) as indicated by the red rectangle in Figure 13. This will detect the UART to Serial cable and show the connection in the list, as shown in Figure 14. If the UART cable is not detected, ensure that the steps in section 2.2 were performed.

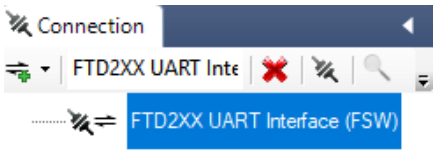

Figure 14 – New Connection in List

2. The baud rate must now be changed from the default 921600 to 115200, as shown in Figure 15 below. The rest of the values can be left at their defaults.

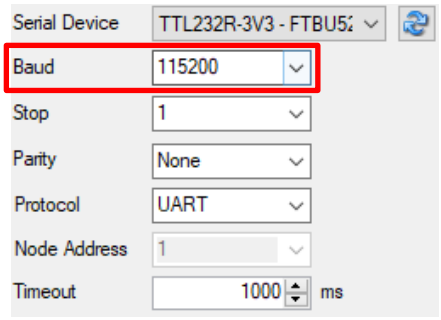

Figure 15 – Baud Rate Selection

3. Connect to CubeStar by clicking on the connect button ( ) shown in Figure 14. The CubeStar user interface should show up as described in the following section. If the interface does not appear, ensure that the UART cable is correctly connected to the CubeSupport PCB and that the *Vbat On* switch is in the on position, as explained in section 2.1.

2.4 User Interface

The user interface is shown in Figure 16. The interface consists of two tabs:

1. The *CubeStar* tab: A wrapper for all available telemetries and telecommands.
2. The *CubeStar- Images* tab: A utility to download images from CubeStar.

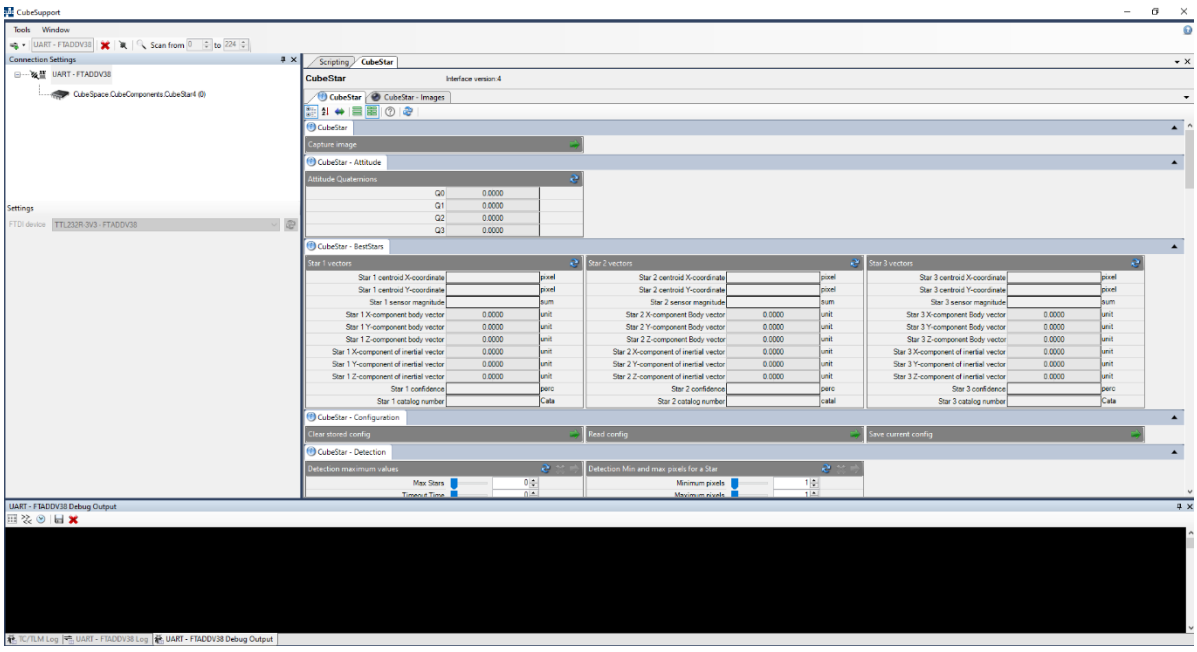

Figure 16 – CubeStar UI

Using this interface, telecommands can be sent with the transmit ( ) buttons and telemetry requests can be made with the refresh ( ) buttons. When settings are changed but have not

yet been transmitted to the CubeStar, the tab heading background will change to orange, as shown in Figure 17. For a more in-depth description of the available telemetries and telecommands, refer to the *CubeStar Reference Manual* [1] and the *CubeStar Interface Control Document* [2].

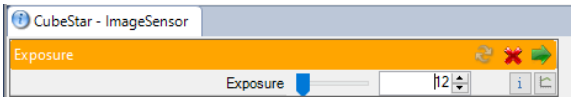

Figure 17 – Orange Tab Indicating Unconfirmed Setting Changes

3. Updating CubeStar Firmware

This chapter describes how to proceed in the case that CubeSpace provides new firmware files that can be uploaded to CubeStar, the steps in this section can be followed to program CubeStar.

3.1 Programming Header

The programming header can be found next to the interface header on the bottom PCB of CubeStar. This header, indicated in Figure 18, is a 2.0 mm pitch, right angle, female header. Pin 1 of the programming header is located on the right-hand side as shown in Figure 18.

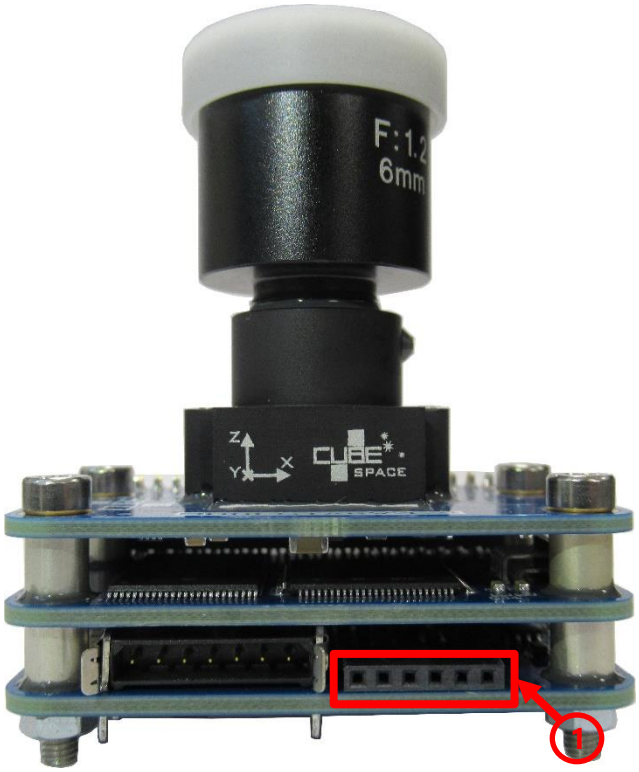

Figure 18 – CubeStar Programming Header

It is recommended to use a SEGGER J-Link debugger to program CubeStar. The *Silicon Labs Energy Micro EMF32* starter kits, such as the *STK3700,* comes with an integrated SEGGER J-Link debugger and can therefore be used as a programmer. Using *Simplicity Commander* (discussed in the following sections), this programmer can be set to output debug mode. In this mode, the SWD lines are disconnected from the onboard MCU and instead connected to the 20-pin debug header. The programmer can then be used to program CubeStar. A conversion is required to convert the 20-pin debug header of the STK3700 to a 6-pin, 2mm pitch, male header to plug into CubeStar's programming header. The required pinouts are summarized in Table 2.

Table 2 – CubeStar Programming Header Pinout

Pin Name	20-pin STK3700 Debug Header	6-pin CubeStar Programming Header
3V3	1	1
SWDIO	7	2
SWCLK	9	3
GND	12	4
SWO	13	5
NRST	15	6

The required programmer and cables are shown in Figure 19.

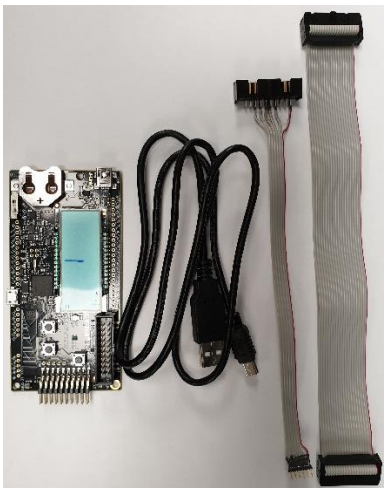

Figure 19 – Hardware Required to Program CubeStar

3.2 Simplicity Commander

Silicon Labs offers a software package named *Simplicity Commander*. This contains the required functionality to upload a new binary to CubeStar via the programmer. This section will guide the user through the process of setting up *Simplicity Commander* to flash a new binary to CubeStar.

3.3 Installing Simplicity Commander

To install *Simplicity Commander*, the web installer must be downloaded from the *Silicon Labs* website. Using your web browser navigate to the link below:

https://www.silabs.com/developers/mcu-programming-options

Please note that new versions of the software are released regularly, and the newest software might not look the same as recorded in this document. However, the process, options and functionality should remain the same.

Download the *Windows Installer* and install *Simplicity Commander* once the download is complete.

3.4 Programmer setup

Once *Simplicity Commander* has been installed, open the *Simplicity Commander* application. An example of this application view is shown in Figure 20.

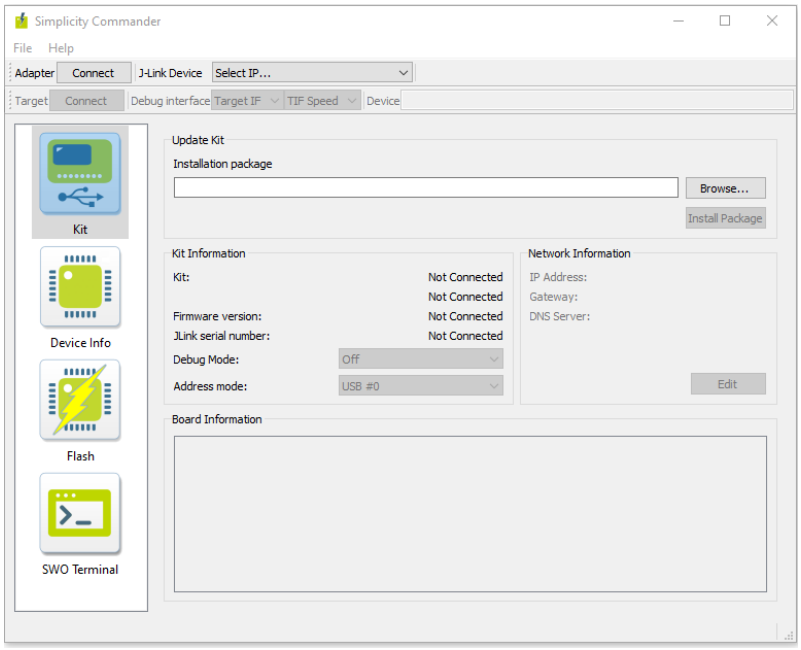

Figure 20 – Simplicity Commander Interface

Notice that the programmer can be selected under the *J-Link device* dropdown menu, as shown in Figure 21 below, once it has been connected to the PC. Select the programmer and connect to it with the *Connect* button.

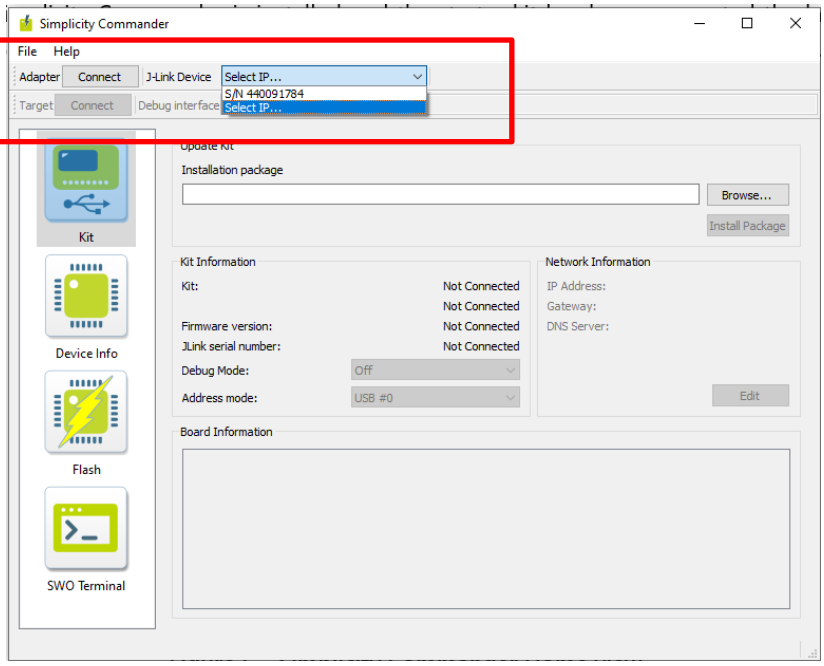

Figure 21 – Connecting to the Starter Kit

Navigate to the *Kit* tab and set the *Debug Mode:* to *OUT*. An LED will light up next to the 20-pin debug header on the programmer, indicating that the programming interface is in *Out* mode. All other options should be left as default.

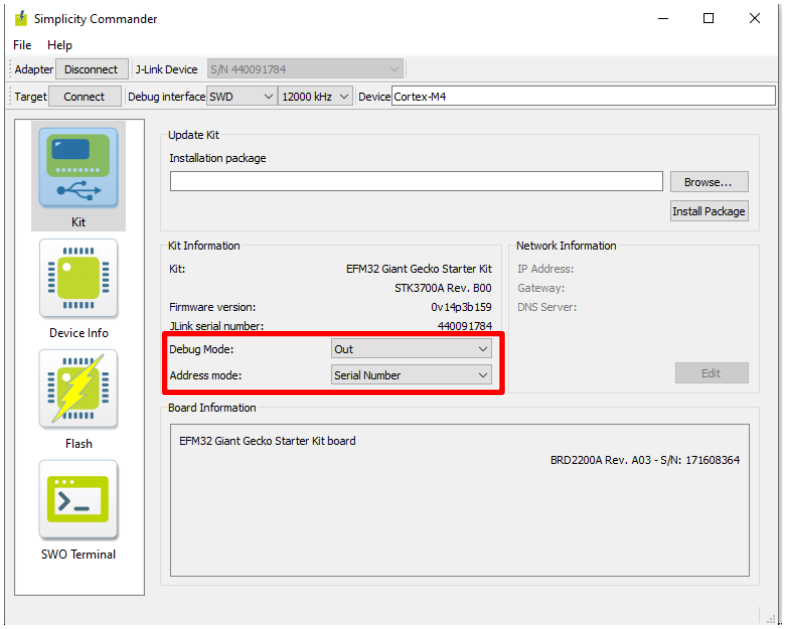

Figure 22 – Setting Debug Mode

Your programmer should now be ready to program an external target.

3.5 Programming CubeStar

Follow the steps below to upload a firmware binary file to CubeStar:

1. Connect the programmer to the PC using the USB cable.
2. Connect the 20-pin header ribbon cable to the programmer ensuring that the red wire is connected to pin one.
3. Connect the 20-pin to 6-pin conversion cable.
4. Connect the 6-pin male end of the programming cable to CubeStar ensuring pin one of the cable is plugged into pin one of the header as described in section 3.1.
5. Power on CubeStar [1]. The final setup is shown in Figure 23.

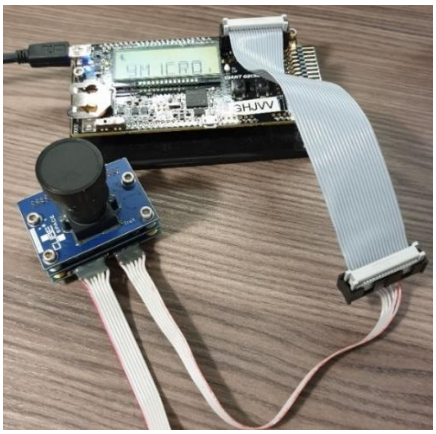

Figure 23 – CubeStar Connected to programmer

6. Once CubeStar has been powered up and connected to the programmer, click on the *Connect* button in *Simplicity Commander* as shown in Figure 24.

[1] For instructions on how to power CubeStar through the ADCS, please see Section 3.6

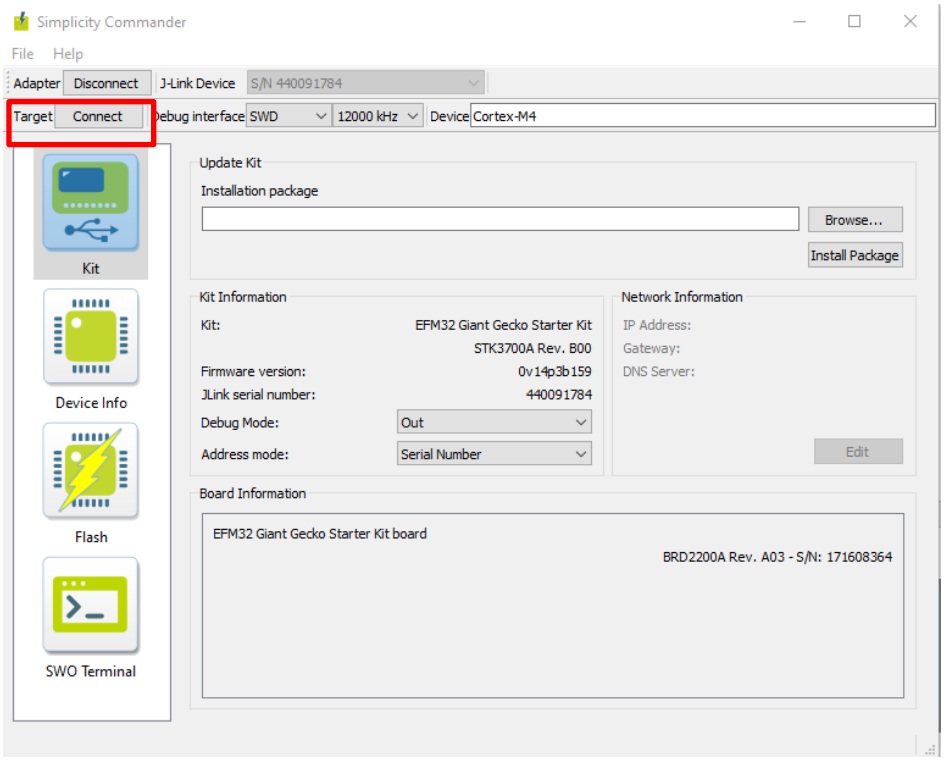

Figure 24 – Connecting to the Target

7. The device type should automatically be detected. If not, ensure that the CubeStar is set up correctly according to sections 2.1 and 3.1. When navigating to the *Device Info* tab, all necessary information about the target chip should be displayed, as shown in Figure 25.

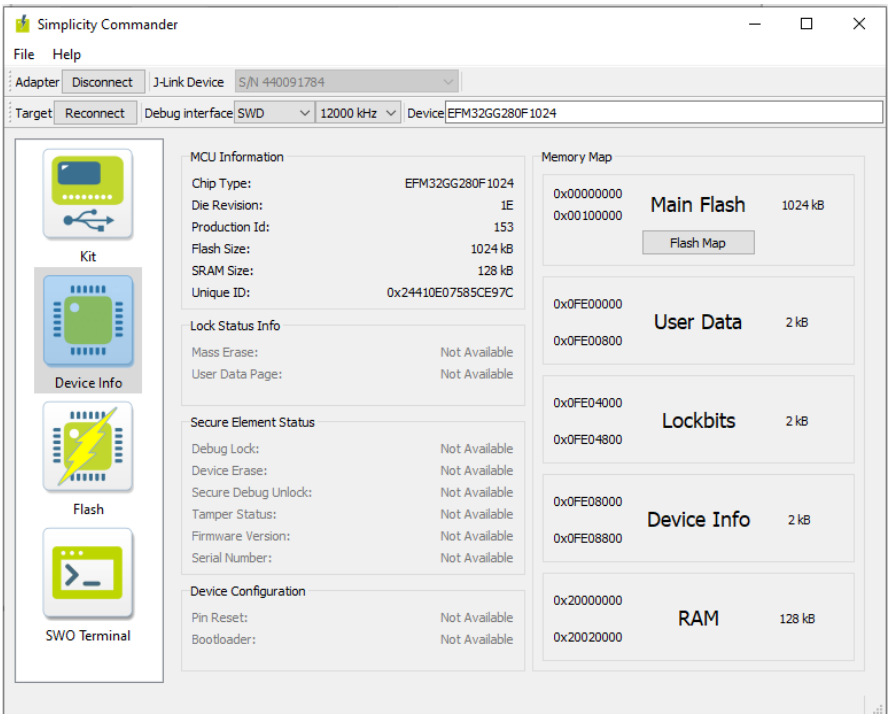

Figure 25 –Device Info Tab

8. To flash the binary file, navigate to the *Flash* tab, as shown in Figure 26.

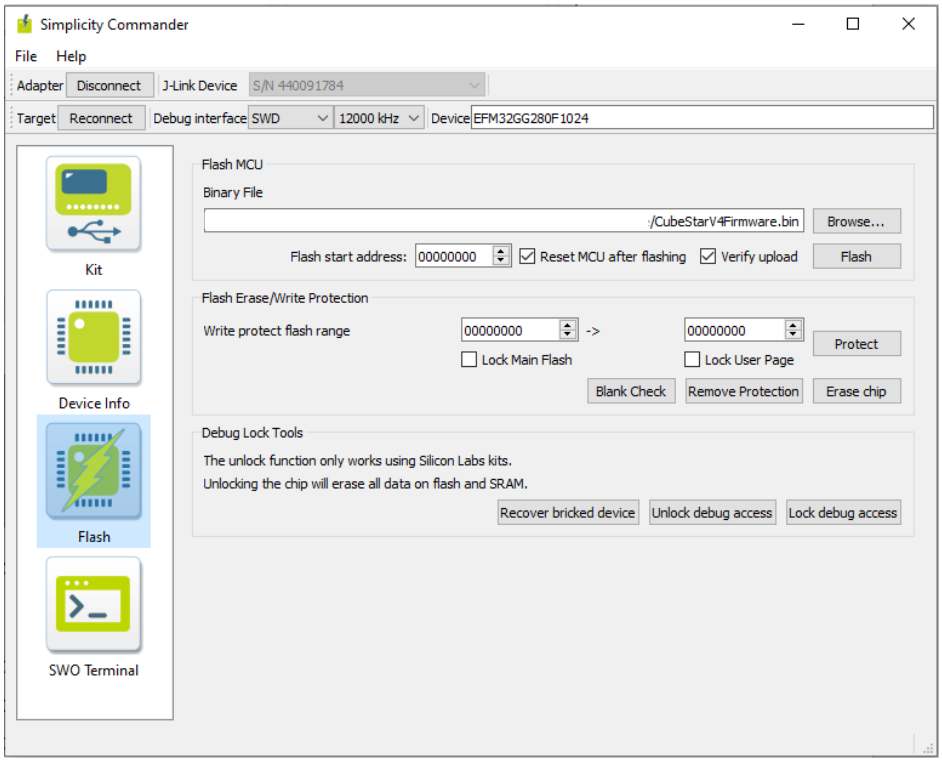

Figure 26 – Flashing the Binary File

9. Set all options as shown in Figure 26.

10. Click the *Browse* button and navigate to the provided *.bin* file containing the CubeStar firmware.
11. Select the *.bin* file and click on the *Flash* button.
12. A pop-up window will appear showing the progress of the firmware upload.
13. If the pop-up window closes and no errors appear, the new firmware was successfully uploaded to CubeStar.

Once the process is complete, disconnect the programming cable and power-cycle the CubeStar.

3.6 Powering CubeStar whilst connected to the ADCS

It is possible to reprogram CubeStar while it is connected to the ADCS. To be able to power CubeStar during this configuration, the following steps should be followed:

1. Turn on the ADCS power.
2. Wait 5 seconds and connect to the ACP program running on the CubeComputer by using the CubeSupport application.
3. In the CubeSupport application, enable the ADCS run mode by navigating to the *ADCS* → *Adcs 3-Axis* → *ADCS Run Mode* and selecting *AdcsEnabled*, as shown in Figure 27.

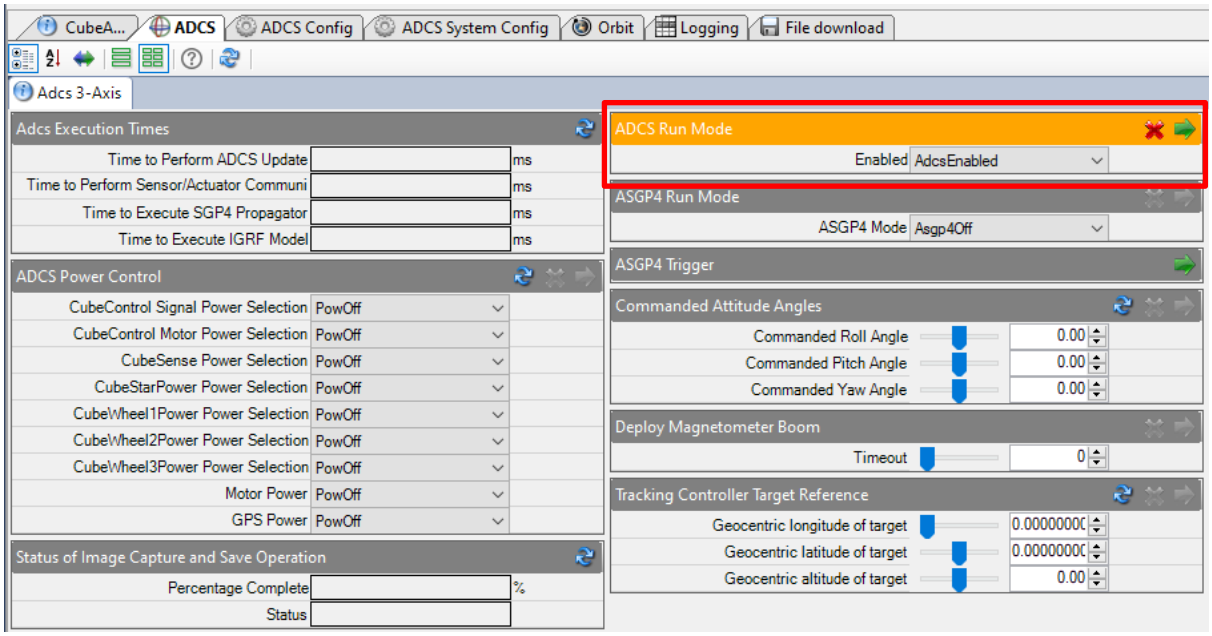

Figure 27 – Enabling ADCS Run Mode

4. Under *Adcs 3-Axis* → *ADCS Power Control* set CubeStar Power Selection to *PowOn*

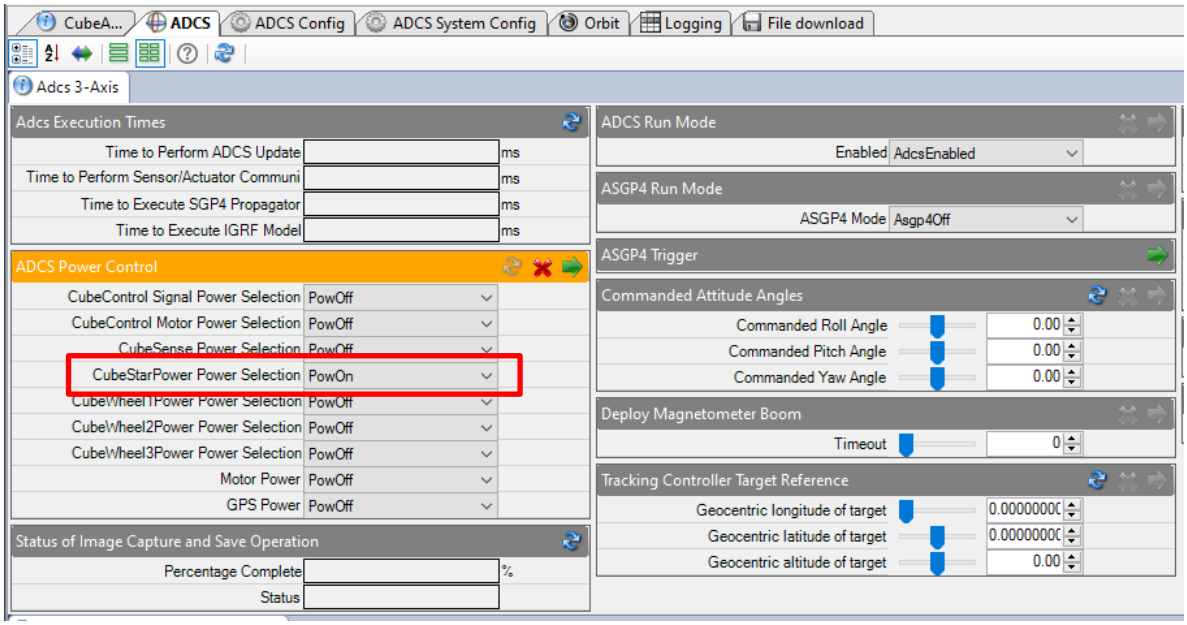

Figure 28 – Powering On CubeStar

5. Now, disable *ADCS Run Mode* by navigating to the *ADCS* → *Adcs 3-Axis* → *ADCS Run Mode* tab and selecting AdcsOff, as shown in Figure 29.

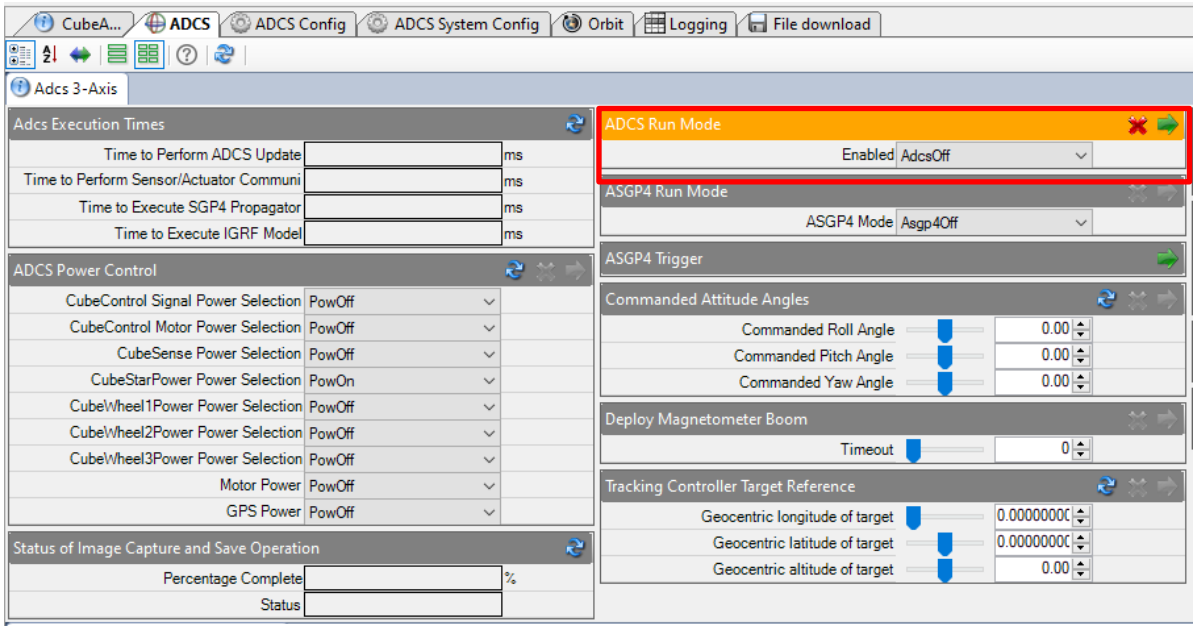

Figure 29 – Disabling ADCS Run Mode

The CubeStar unit should now be powered on, and ready to be reprogrammed by following the steps in Section 4.5.

4. Appendix A: Health Check and Results

This chapter provides the steps required to perform a health check on CubeStar to determine if it is working as it should. This section is only applicable to clients who bought CubeStar as a standalone unit. The results must be completed and returned as a digital copy to CubeSpace along with the captured image and test pattern.

CubeStar can be tested with or without the lens cap on the lens. In this chapter, values marked with (value)^{C} shows the values expected with a lens cap, and values marked with (value)^{NC} shows values expected without a lens cap.

Please complete Table 2 to allow CubeSpace to identify the CubeStar and supply CubeSpace with other details that might be required in the future.

Table 2 – CubeStar Details

Company/university/institution:	
Contact person:	
Email of contact person:	
Satellite name (if applicable):	
CubeStar Serial number:	
CubeStar Hardware Version:	
Person(s) responsible for Health Check testing:	
Date Health Check was performed:	

Always take the necessary precautions for ESD protection when handling CubeStar. Always handle CubeStar in a clean area or cleanroom. Extra care must be taken to keep the lens clean.

Before handling, please note that CubeStar is highly sensitive. If the lens is moved or turned in the lens holder, the pre-programmed calibration values will no longer be valid, and CubeStar will no longer function correctly. Even a slight shift in lens position will affect the performance of CubeStar. It is also essential to design mounting supports for the lens in the satellite to prevent the lens from shifting due to launch vibrations

4.1 Validating Status and Power

Navigate to the *CubeStar* → *CubeStar - Status* tab as shown in Figure 30.

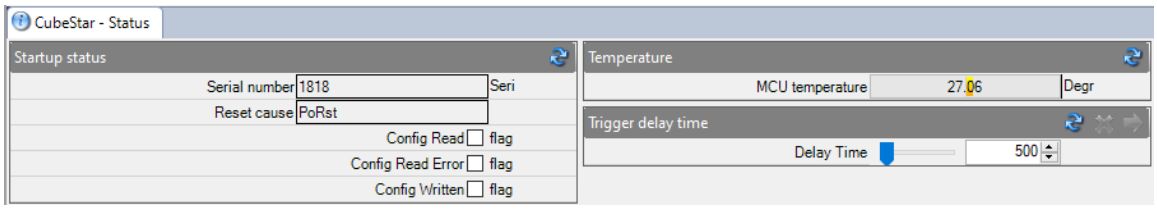

Figure 30 - CubeStar Status Tab

1. Click on the button next to the *Startup Status* heading.
2. Click on the button next to the *Temperature* heading.
3. Note all the values in Table 4.

Navigate to the *CubeStar* → *CubeStar - Errors* tab as shown in Figure 31.

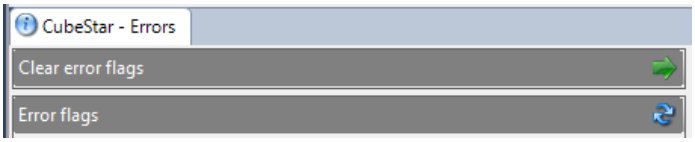

Figure 31 - CubeStar Errors Tab

4. Click on the button next to the *Error Flags* heading.
5. Check that all flags are not checked.
6. Note the results in Table 4.

Navigate to the *CubeStar* → *CubeStar - Power* tab as shown in Figure 32.

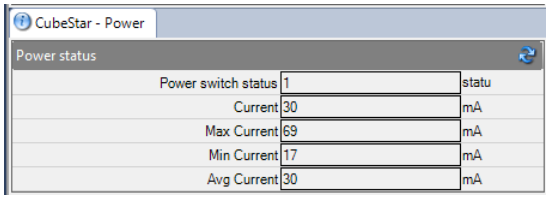

Figure 32 - CubeStar Power Tab

7. Click on the button next to the *Power Status* heading.
8. Note all the values in Table 4.

Table 4 – Status and Power

Test / Task	Expected Result	Result
CubeStar – CubeStar Status → Startup Status		
Serial Number	XXXX	
Reset Cause	PoRst	
Config Read	Unchecked	
Config Read Error	Unchecked	
Config Written	Unchecked	
MCU Temperature	Room Temperature ± 10 °C	
CubeStar – CubeStar Power → Error Flags		
All Flags	Unchecked	
CubeStar – CubeStar Power → Power Status		
Power Switch Status	Enabled (1)	
Current	30 ± 3 mA	
Max Current	70 ± 8 mA	
Min Current	18 ± 4 mA	
AVG Current	30 ± 6 mA	

4.2 Performing an SRAM test

Navigate to the *CubeStar* → *CubeStar - Test* tab as shown in Figure 33.

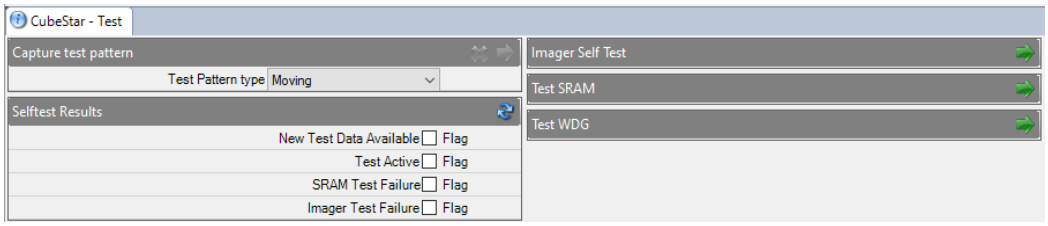

Figure 33 – CubeStar Test Tab

1. Click on the button next to the *Test SRAM* telecommand and wait for roughly 20 seconds.
2. Request the *Selftest Results* telemetry by clicking on the button next to the *Selftest Results* Heading.
3. If the test is not completed yet, the *Test Active* flag will show a checkmark, continue to request the results until this flag is not checked.
4. If the test is completed, the *New Test Data Available* flag will show a checkmark.
5. If the *SRAM Test Failure* flag, together with the *New Test Data Available* flag, shows a checkmark, the SRAM test has failed.
6. If the test failed, note a value of (1) in Table 5, otherwise note a value of (0) to indicate that the test passed.

Table 5 – SRAM Test

Test / Task	Expected Result	Result
CubeStar → CubeStar - Test → Current ADCS State		
SRAM Test Results	Test Passed (0)	

4.3 Testing CubeStar Execution

1. Navigate to the *CubeStar* → *CubeStar – Processing* → *Trigger one-second loop* tab, and send the telecommand by clicking on the button as shown in Figure 34:

Figure 34 – CubeStar Trigger Tab

2. This sets the internal *capture and process* flag that is used to schedule a single sample instance.
3. Complete Table 6 by recording the appropriate values after the one-second loop have been triggered.

Table 6 – Operations

Test / Task	Expected Result	Result
CubeStar → CubeStar Power → Power Status		
Current	20 - 40 mA	
CubeStar → CubeStar - Log → Performance Parameters		
Number of Stars Detected	Zero	
Star Noise	$(30\text{-}330)^{C}$ $(0)^{NC}$	
Number of Stars Identify	Zero	
Identification Mode	Lost	
Image Dark Value	$(0)^{C}$ $(253\text{-}255)^{NC}$	
Image Capture Success	Checked	
Detection Success	Checked	
Identification Success	Unchecked	
Attitude Success	Unchecked	
Processing Tim Error	Unchecked	
Tracking Module Enabled	Unchecked	
Prediction Enabled	Unchecked	
Comms Error	Unchecked	
CubeStar → CubeStar Timing → Timing Summary		
Capture	680 ± 20 ms	
Detection	>250 ms	
Identification	< 10 ms	
CubeStar → CubeStar Best Star → Star vectors		
Star 1 Vectors	All Zeros	
Star 2 Vector	All Zeros	
Star 3 Vectors	All Zeros	

Test / Task	Expected Result	Result
CubeStar → CubeStar Attitude → Attitude Quaternions		
Q0	Zero	
Q1	Zero	
Q2	Zero	
Q3	Zero	

4.4 Validate Calibration Parameters

1. Navigate to the *CubeStar* → *CubeStar - Lens* tab as shown in Figure 35:

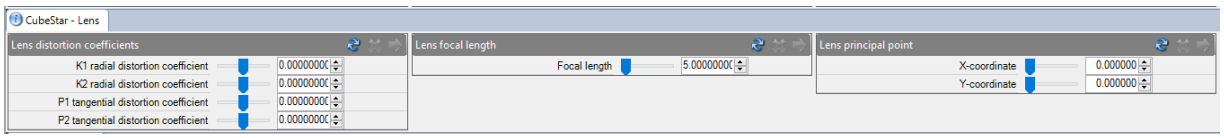

Figure 35 – CubeStar Lens Tab

2. Request the *Lens distortion coefficients, Lens focal length*, and *Lens Principal point* values with the  button.
3. Note the values in Table 7.
4. Navigate to the *CubeStar* → *CubeStar - Detection* tab as shown in Figure 36.

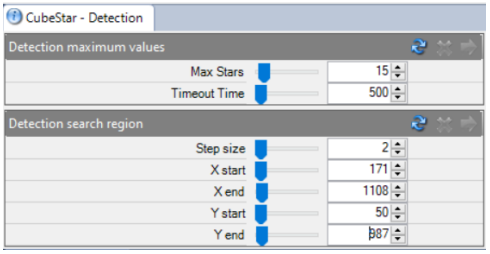

Figure 36 – CubeStar Detection Tab

5. Request the *Detection search region* values with the  button.
6. Complete Table 7 and compare the results with the values noted in the delivery report of the CubeStar.

Table 7 – Calibration Parameters

Test / Task	Expected Result	Result
CubeStar → CubeStar Lens → Lens distortion coefficients		
K1 radial distortion coefficient	Matches delivery report	
K2 radial distortion coefficient	Matches delivery report	
P1 tangential distortion coefficient	Matches delivery report	
P2 tangential distortion coefficient	Zero	
CubeStar → CubeStar Lens → Lens focal length		
Focal length	Matches delivery report	
CubeStar → CubeStar Lens → Lens principal point		
X-coordinate	Matches delivery report	
Y-coordinate	Matches delivery report	
CubeStar → CubeStar Detection → Detection search region		
Step size	2	
X start	Matches delivery report	
X end	Matches delivery report	
Y start	Matches delivery report	
Y end	Matches delivery report	

4.5 Download Image

1. Navigate to the *CubeStar* → *CubeStar – ImageSensor* → *Exposure* tab and set the Exposure to 12, as shown in Figure 37.
2. Transmit the new exposure value with the  button.

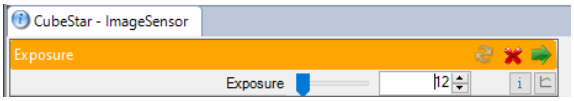

Figure 37 – Setting the Image Sensor Exposure

3. Remove the star tracker lens cap.
4. Navigate to the *CubeStar* → *CubeStar* → *Capture Image* tab and capture an image with the  button.

Figure 38 – Capturing an Image

5. Navigate to the *CubeStar – Images* tab.

Figure 39 – CubeStar - Images tab

6. Click on the *Download* button. Once the image has been downloaded, it will be displayed. This image must be saved by clicking on the *Save* button.
7. An example of a CubeStar image is shown in Figure 40.

Figure 40 – Example CubeStar Image

8. Note a successful image capture in Table 8.

Table 8 – Image Downloaded

Test / Task	Expected Result	Result
Image Captured	The image was downloaded successfully, and the image looks correct (not just white or black)	

4.6 Capture Test Image

1. Navigate to the *CubeStar – Test* tab and select the *Fixed* test pattern as shown in Figure 41. Transmit the command with the button.

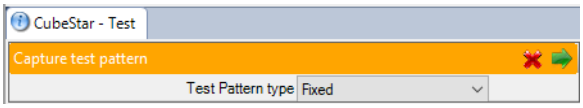

Figure 41 – Capture Test Image Tab

2. A test image would now have been captured to the CubeStar's SRAM.
3. Download and save this image by navigating to the *CubeStar – Images* tab and clicking on the *Download* button. The downloaded image must be similar to the image shown in Figure 42.
4. Note a successful test image capture in Table 9.

Figure 42 – CubeStar Fixed Test Image

Table 9 – Test Pattern Downloaded

Test / Task	Expected Result	Result
Test pattern Captured	Test Pattern was successfully captured and downloaded and looks like the example	

Please complete the preceding health check and return a digital copy of it to CubeSpace along with copies of the captured image and test pattern