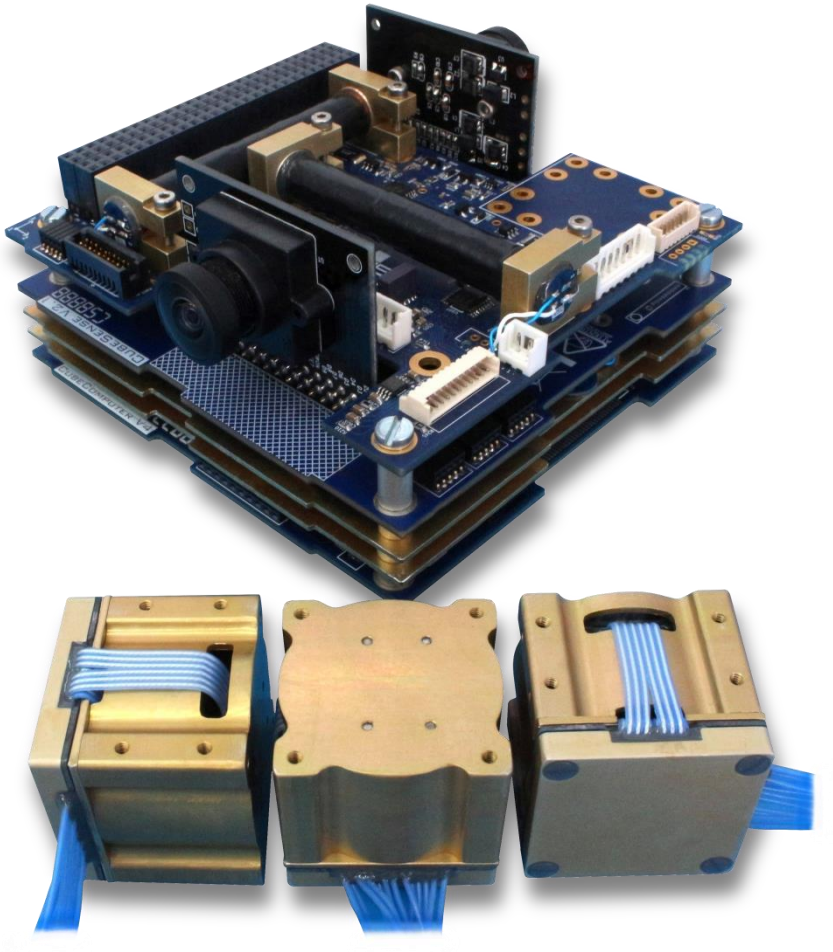
CUBE SPACE

CubeADCS

The complete ADCS solution



Health Check

ESL
Electronic Systems Laboratory

Contact Us

Phone : +27 21 808 9499
E-mail : info@cubespace.co.za
Web : www.cubespace.co.za
Facebook : /CubeSpaceADCS
Twitter : @CubeSpace_ADCS

Physical Address

CubeSpace
The LaunchLab
Hammanshand Road
Stellenbosch, 7600
South Africa

UNIVERSITEIT STELLENBOSCH UNIVERSITY

Document	CubeADCS Health Check
Version	3.15
Domain	Public
Date modified	19 April 2018
Approved by	Name: Mike-Alec Kearney
	Signature: 

List of Acronyms/Abbreviations

ACP	ADCS Control Program
ADCS	Attitude and Determination Control System
CSS	Coarse Sun Sensor
MCU	Microcontroller Unit
PCB	Printed Circuit Board
TC	Telecommand
TLM	Telemetry
UART	Universal Asynchronous Receiver/Transmitter

Table of Contents

1. Health Check Details

CubeADCS unit number: 1812

Date of CubeSpace Health Check: 9 May 2018

Name(s) of CubeSpace engineer(s): Hein Wessels & Christo Groenewald

Signature(s) of CubeSpace engineer(s): H Wessels & C Groenewald

Date of client Health Check:

Name(s) of client engineer(s):

Signature(s) of client engineer(s):

2. Introduction

This document will provide the instructions and results of the health check of the CubeADCS unit. The instructions provided must be followed exactly and the observed results must be indicated as is.

2.1 Handling

The CubeADCS unit contains electrostatic sensitive components. Under no circumstances should the unit be handled without anti-static protection.

The CubeADCS unit is a delicate mechanical assembly. Always handle with great care, preferably using anti-static gloves.

When handling the CubeADCS unit, always place the unit on an anti-static mat in a clean environment, as required for flight-model components.

2.2 Test requirements

The following items are required when performing the health check:

- Power supply (V_{max} > 10 V, I_{max} > 1 A).
- An appropriate power distribution platform with 5 V and 3.3 V regulators.
- Latest CubeSupport software (Provided on USB with CubeADCS).
- The supplied UART-to-USB cable.
- The supplied CubeADCS unit and all peripherals.
- Any means of measuring the direction of a magnetic field, for example a normal field compass.
- A small bright light source to stimulate the Coarse Sun Sensors and Sun cameras (if any). Typically, a modified LED flash light (see Figure 1) to create a narrow source, or mobile phone flash, will suffice.

Signature of tester(s): H Wessels & C Groenewald

Figure 1 – Example of modified LED Torch

- A broad bright light source to stimulate the Nadir camera's (if any). Typically, a desk lamp covered with paper will suffice (see Figure 2).

Figure 2 – Example of modified Desk Lamp

2.3 Preparation

Follow the instructions below to prepare the CubeADCS for the health check:

- Connect all peripherals to the CubeADCS. This normally includes:
  - Magnetometer
  - Coarse Sun Sensors
  - CubeSense (typically if 3-Axis and/or Y-Momentum capable)
  - Redundant Magnetometer (optional)
  - GPS (optional)
  - Multiple reaction wheels (typically if 3-Axis capable)
  - CubeStar (optional if 3-Axis capable)
- Set the power supply to the correct battery voltage and the current limit to I_{max} = 1 A and connect the supply to the power distribution platform.
- Power down the power supply while it is being connected to the CubeADCS
- Connect power leads to the appropriate PC104 pins on the CubeADCS unit. Refer to the CubeADCS Interface Control Document and the Option Sheet for the relevant PC104 pin locations.
- Connect the UART-to-USB cable to CubeComputer. **NB: The black wire (Ground) should be connected to the pin closest to the corner of the PCB farthest away from the PC104 connector.**

Signature of tester(s): H Wessels & C Groenewald

3. CubeComputer

Once the preparation in the preceding section has been completed the CubeADCS should be ready for the health check to start. Before powering on the ADCS read though the following subsection to insure everything is clear before you start the procedure. Please look at the last check list before starting the health test.

- Power supply is set to correct battery voltage
- Power supply current limit is set to 1A or more
- Power supply is off
- Power leads connecting to CubeADCS are short to keep series resistance as small as possible
- All peripherals are securely connected to the ADCS
- CubeADCS is placed in a secure clean grounded are with enough room for users to move a light source around the ADCS and the peripherals are placed for easy access and control.
- CubeADCS is connected to PC though UART to Serial cable.
- Do not power on the CubeADCS.

3.1 The Bootloader

Once power is turned on, the bootloader will initialize. If the bootloader does not receive communications within 5 seconds it will load the previously specified application. The bootloader will boot the same project only four times before the boot counter runs out. Once the boot counter runs out the bootloader will not boot the specified application automatically, this will result with the bootloader waiting for the user to specify that the application should be loaded again.

For the health check first connect to the bootloader and specify that the ACP should be loaded. This is achieved with the following steps.

Before powering on the ADCS, ready the CubeSupport application on the PC. The CubeSupport application is supplied on a USB along with the bundle. Launch the CubeSupport application .exe which can be found in the CubeSupport folder on the CubeSpace USB. The CubeSupport application will open a window as shown in Figure 3.

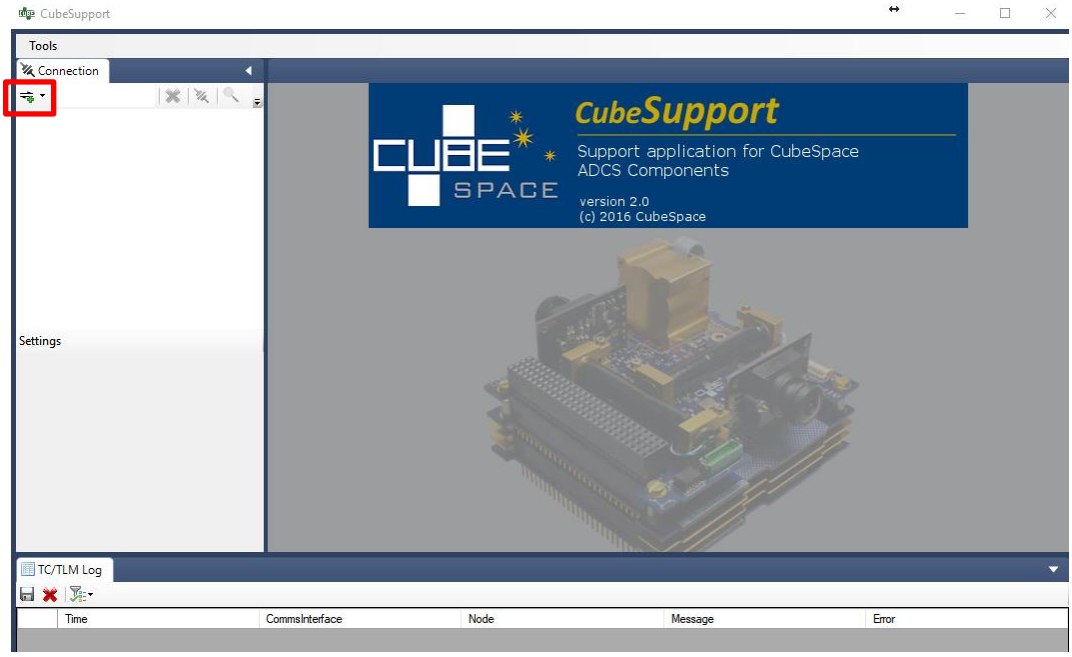


Figure 3 – Add connection to CubeSupport

Click on the add connection icon  in CubeSupport as shown with the red rectangle in Figure 3.This will detect the UART to Serial cable and show the connection in the list.

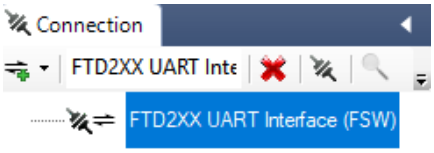


Figure 4 – New Connection in list

Now Power on die CubeADCS and wait 1 second for everything to power on, connect to the ADCS with CubeSupport within the first five seconds of power on by clicking on the connect button  . CubeSupport should catch the bootloader and connect to the ADCS bootloader, the bootloader menu will be displayed as shown in Figure 5.

Signature of tester(s): H Wessels & C Groenewald

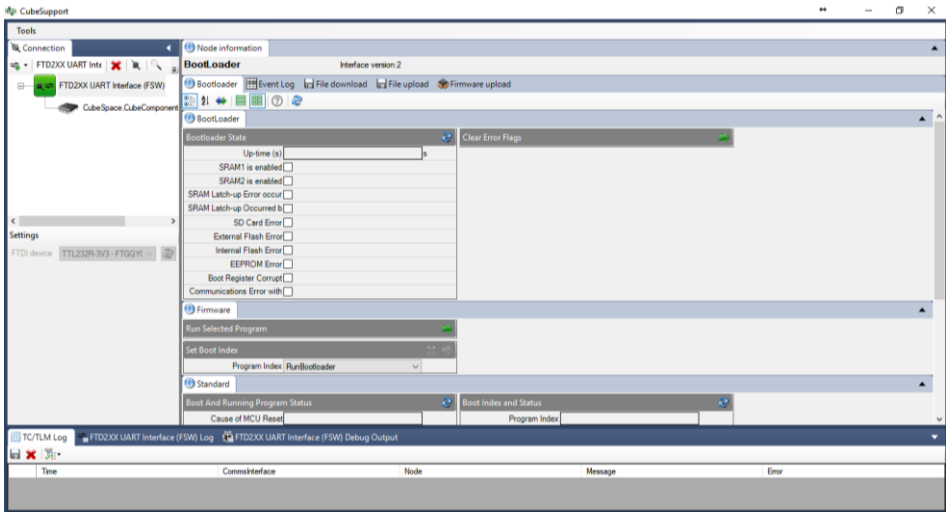


Figure 5 – CubeSupport Bootloader Interface

On the Bootloader tab there are a couple of telemetry windows which displays the bootloader information. Click on the refresh icon  to read the data from CubeComputer. Ensure that the data is the same as given in Table 1.

Table 1 - Bootloader data

Variable	Expected Result	Observed Result	User Observed Result
Bootloader -> Bootloader State			
Up-time (s)	Incrementing every second	✓	
SRAM 1 is enabled	Checked	✓	
SRAM 2 is enabled	Checked	✓	
SRAM Latch-up Error occurred	Unchecked	✓	
SRAM Latch-up Occurred b	Unchecked	✓	
SD card Error	Unchecked	✓	
External Flash Error	Unchecked	✓	
Internal Flash Error	Unchecked	✓	
EEPROM Error	Unchecked	✓	
Boot Register Corrupt	Unchecked	✓	
Communications Error	Unchecked	✓	
Standard-> Boot and Running Program Status			
Cause of MCU Reset	PowerOnReset	✓	
Boot Cause	Unexpected	✓	
Boot Counter	Incrementing at every reset	✓	
Boot Program Index	RunEeprom	✓	
Firmware version (Major)	2	✓	

Signature of tester(s): H Wessels & C Groenewald

Firmware version (Minor)	1	✓	
Standard -> Boot Index and Status			
Program Index	RunInternalFlashProgram	✓	
Boot Status	BootSuccess	✓	
Standard – Satellite State			
Telecommand counter	0	✓	
Telemetry request counter	Incrementing after every refresh	✓	
TC buffer overrun	Unchecked	✓	
UART protocol error	Unchecked	✓	
UART incomplete message	Unchecked	✓	

In the Firmware section under the Set Boot Index sub-section set the program index to *RunInternalFlashProgram* as shown in Figure 6.

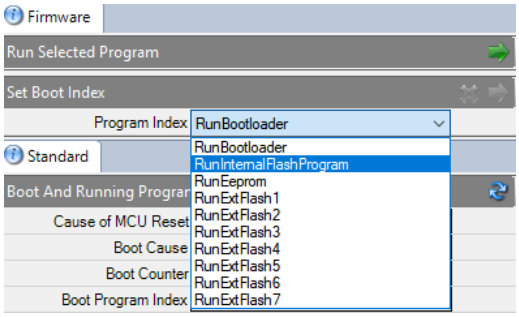
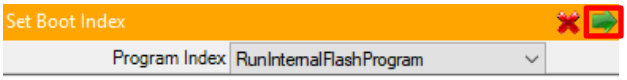


Figure 6 – Set boot index

Transmit the command by clicking on the green arrow after setting the boot index.



The ADCS is delivered with the ACP pre-loaded into the internal flash and setting the boot index to the internal flash will insure that the application is executed.

Power off the CubeADCS and disconnect the CubeSupport by clicking on the disconnect icon .

Turn on the CubeADCS and wait for 6 seconds to pass before attempting to connect with CubeSupport. The bootloader will execute the ACP after 5 seconds. The CubeSupport application can connect to the ACP application and the CubeSupport will display the window shown in Figure 7.

Signature of tester(s): H Wessels & C Groenewald

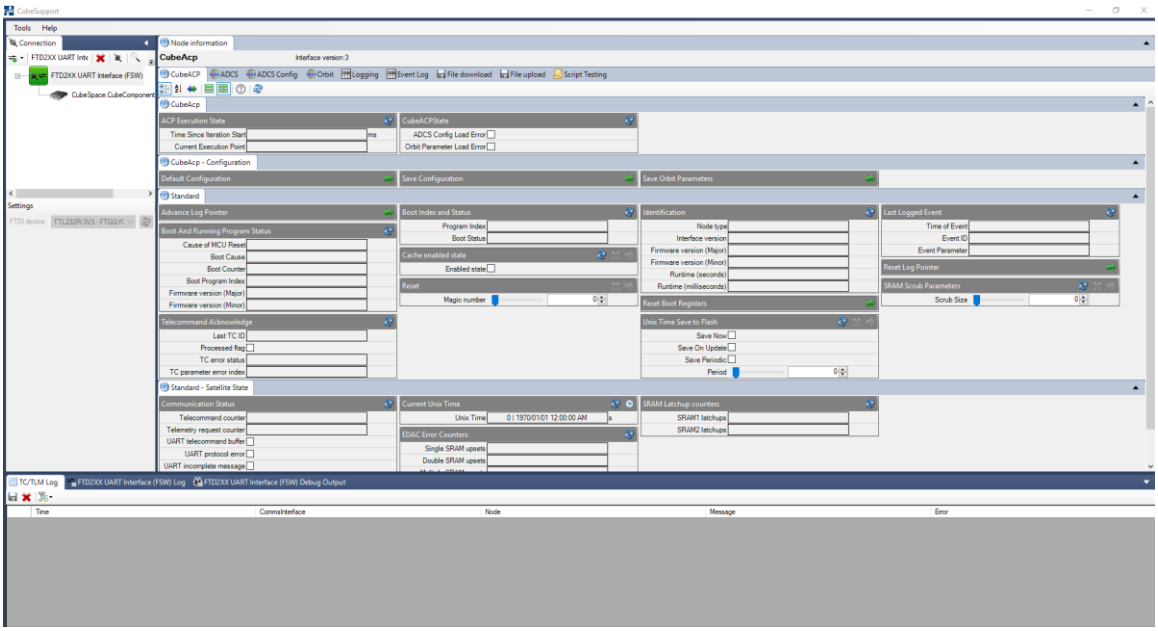


Figure 7 – CubeSupport Connected to ACP

Alternative to turning the CubeADCS off and on, the *Program Index* can be set and the *Run Selected Program* command can be transmitted. This will cause the bootloader to boot the application.

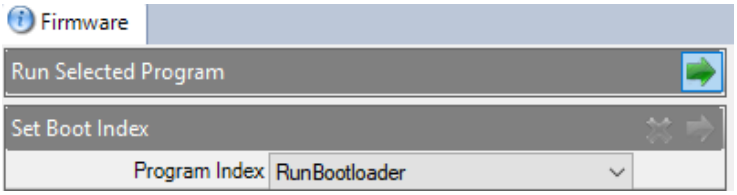
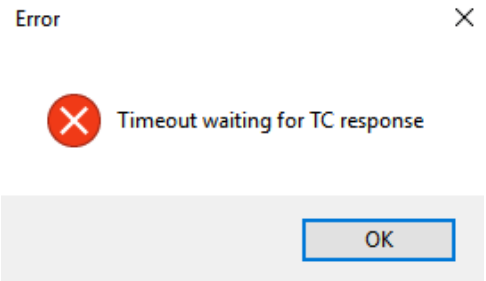


Figure 8 – Run Selected Program

An error message will be display reporting that the no response was obtained since the bootloader started to boot the ACP.



Click "OK", disconnect  and reconnect  to connect to the ACP and show the ACP interface.

Signature of tester(s): H Wessels & C Groenewald

3.2 The CubeACP

Verify that the CubeSupport connects to the ACP.

Test / Task	Expected Result	Observed Result	User Observed Results
CubeComputer connects to the CubeSupport application.	✓	✓	

- Navigate to the *CubeACP* tab.
- Verify the following under the *CubeACP* tab by refreshing the data in the relevant box several times (click on the  button to refresh the data):

Test / Task	Expected Result	Observed Result	User Observed Results
CubeACP → ACP Execution State			
Time Since Iteration Start	0-1000	✓	
Current Execution Point	Idle	✓	
Standard → Boot and Running Program Status			
Cause of MCU Reset	Power on reset	✓	
Boot Cause	Unexpected	✓	
Boot Counter	Increment after every reset	✓	
Boot Program Index	RunInternalFlashProgram	✓	
Firmware Version (Major)	3	✓	
Firmware Version (Minor)	11	✓	
Standard → Identification			
Node type	10	✓	
Interface Version	3	✓	
Runtime (seconds)	Incrementing every second	✓	
Runtime (milliseconds)	0 – 1000	✓	
Standard → Boot Index and Status			
Program Index	RunInternalFlashProgram	✓	
Boot Status	BootSuccess	✓	
Standard → Satellite State → Communication Status			
Telecommand counter	0	✓	

Signature of tester(s): H Wessels & C Groenewald

Telemetry request counter	Incrementing	✓	
TC buffer overrun	Unchecked	✓	
UART protocol error	Unchecked	✓	
UART incomplete message	Unchecked	✓	
Standard → Satellite State → Current Unix Time			
Unix Time	Incrementing	✓	
Standard → Satellite State → SRAM Latchup Counters			
SRAM1 Latchups	0	✓	
SRAM2 Latchups	0	✓	
Standard → Satellite State → EDAC Error Counters			
Single SRAM upsets	0	✓	
Double SRAM upsets	0	✓	
Multiple SRAM upsets	0	✓	

- Navigate to the *ADCS* tab.
- Verify the following under the *ADCS* tab by refreshing the data in the relevant box several times:

Test / Task	Expected Result	Observed Result	User Observed Results
Adcs 3-Axis → ADCS Power Control			
All nodes indicate PowOff	PowOff	✓	
Adcs 3-Axis → ADCS State → Current ADCS State			
ADCS Run Mode	AdcsOff	✓	
Attitude Estimation Mode	EstNone	✓	
Control Mode	ConNone	✓	
All other states indicated with check boxes	Unchecked	✓	

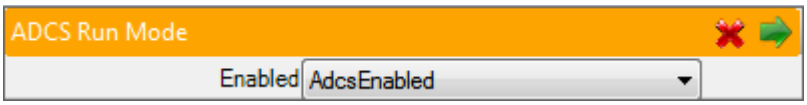
Once all the parameters above have been verified, it can be confirmed that CubeADCS is operating normally. The following sections of this Health Check document will be dedicated to testing the functionality of the other ADCS nodes in the CubeADCS unit.

Signature of tester(s): H Wessels & C Groenewald

4. CubeSense

Follow the instructions below to perform the CubeSense health check (if the CubeADCS is equipped with a CubeSense):

- Navigate to the *ADCS* tab.
- In the *Adcs 3-Axis → ADCS Run Mode* box, switch the run mode to *AdcsEnabled*. Note that the top of the box turns orange with a red cross and a green arrow once the relevant run mode has been selected. **Click on the green arrow to confirm and send the command to the CubeADCS unit**. Conversely, clicking on the red cross will ignore and discard the command.



Confirm that the ADCS is enabled by reading the values indicated in the tables below (refresh the data in the relevant boxes).

Test / Task	Expected Result	Observed Result	User Observed Results
Adcs 3-Axis → ADCS Execution Times			
Time to Perform ADCS update	105 ± 25 ms	85 ms ✓	
Time to Perform Sensor/Act	3 ± 3 ms	0 ms ✓	
Time to Execute SGP4 Prop	46 ± 10 ms	42 ms ✓	
Time to Execute IGRF Mode	50 ± 10 ms	42 ms ✓	
Adcs 3-Axis → ADCS State → Current ADCS State			
ADCS Run Mode	AdcsEnabled	✓	
Attitude Estimation Mode	EstNone	✓	
Control Mode	ConNone	✓	
Sun is Above Local Horizon*	Checked	✓	
All other Checkboxes**	Unchecked	✓	

* If ***Sun is Above Local Horizon*** is **not** checked the *CubeADCS* expects to be in the eclipse part of its orbit according to the Unix time (or when ***Capture Status*** reads ***CaptureStartup***). This means the CubeACP will **not** sample the raw CubeSense outputs. If this happens change the *CubeACP*'s Unix time to "move" the satellite out of eclipse. This is done at *CubeACP → Standard → Satellite State → Current Unix Time*. (Normal flight software is used for Health Check).

** Note that the following flags can be ignored, as they are dependent on the setup, environment, and stimulus:

1. Magnetometer Range Error
2. Cam1 Sensor Detection Error
3. Cam1 Sensor Range Error

Signature of tester(s): H Wessels & C Groenewald

4. Cam2 Sensor Detection Error
5. Cam2 Sensor Range Error
6. Coarse Sun Sensor Error

- **Switch on CubeSense** by selecting *PowOn* in the drop-down menu next to *CubeSense Power Selection* in the *ADCS Power Control* box (*ADCS 3-Axis* tab) and transmit the command by clicking on the green arrow.
- Ensure that the **lens caps** of **both cameras** are **on**.
- Navigate to the *ADCS Config* tab and read the ADCS configuration. Scroll down to Cam1 and Cam2 sensor configuration (there are nine values in total per sensor) and make a note of all these values.
- Navigate to the *Adcs 3-Axis* → *Configuration* → Set *Cam1 Sensor Configuration* block and copy **all** the Cam1 values as you noted in the ADCS configuration block. Change the ***Cam1 detection threshold* to 150**. Set the ***Cam1 sensor exposure time*** to 35 if Cam1 is a Nadir sensor, or to 100 if Cam1 is a Sun sensor. Click on the green arrow to send these commands.
- Navigate to *Adcs 3-Axis* → *Configuration* → *Set Cam2 Sensor Configuration* block and copy **all** the Cam2 values as you noted in the ADCS configuration block. Change the ***Cam2 detection threshold* to 150**. Set the *Cam2* ***sensor exposure time*** to 35 if Cam2 is a Nadir sensor, or to 100 is Cam2 is a Sun sensor. Click on the green arrow to send these commands.
- Navigate back to the *ADCS* tab and verify the following values:

Test / Task	Expected Result	Observed Result	User Observed Results
Adcs 3-Axis → ADCS State → Current ADCS State			
ADCS Run Mode	AdcsEnabled	✓	
Attitude Estimation Mode	EstNone	✓	
Control Mode	ConNone	✓	
CubeSense Enabled	Checked	✓	
Sun is Above Local Horizon*	Checked	✓	
All other checkboxes**	Unchecked	✓	
Adcs 3-Axis → ADCS Power → CubeSense Current Measurements			
CubeSense 3V3 current	35 ± 7 mA	34.9 mA ✓	
Cam1 SRAM current	< 2 mA	0 mA ✓	
Cam2 SRAM current	< 2 mA	0 mA ✓	
Adcs 3-Axis → Raw Sensor Measurements → Raw Cam1 Sensor			

Signature of tester(s): H Wessels & C Groenewald

Cam1 centroid X	0	✓	
Cam1 centroid Y	0	✓	
Capture Status*	CaptureSuccessOwn	✓	
Detection Result	DetectTooFewEdges or DetectSunNotFound	✓	
Adcs 3-Axis → Raw Sensor Measurements → Raw Cam2 Sensor			
Cam2 centroid X	0	✓	
Cam2 centroid Y	0	✓	
Capture Status*	CaptureSuccessOwn	✓	
Detection Result	DetectTooFewEdges or DetectSunNotFound	✓	

* If ***Sun is Above Local Horizon*** is **not** checked the *CubeADCS* expects to be in the eclipse part of its orbit according to the Unix time (or when ***Capture Status*** reads ***CaptureStartup***). This means the CubeACP will **not** sample the raw CubeSense outputs. If this happens change the *CubeACP*'s Unix time to "move" the satellite out of eclipse. This is done at *CubeACP* → *Standard* → *Satellite State* → *Current Unix Time*. (Normal flight software is used for Health Check).

** Except for the aforementioned error flags.

- Take **off** the **Cam1 camera**'s **lens cap**.
- Verify the following from the *Adcs 3-Axis* → *Raw Sensor Measurements* → *Raw Cam1* box by testing the sensor with a light source (a dark environment will prevent false detections). If Cam1 is a **Nadir** sensor then a **large** light source should be used (e.g. a desk lamp), or if Cam1 is a **Sun** sensor then a **small** light source should be used (e.g. narrow beam flash light). Vary the distance between the light source and the sensor until consistent measurements are observed (normally ±150mm). If difficulties are experienced with the Nadir sensor then the light source can be covered with white paper/cloth to create a more uniform light source. Finally, if no results are obtained for the Nadir or Sun sensors the exposure value can be adjusted.

Test / Task	Expected Result	Observed Result	User Observed Results
Adcs 3-Axis → Raw Sensor Measurements → Raw Cam1 Sensor			
Detection Result	DetectSuccess	✓	
Capture Status*	CaptureSuccessOwn	✓	
Centroid Y when placing the light close to the camera boresight	Close to zero	✓	

Signature of tester(s): H Wessels & C Groenewald

Centroid Y when moving the light **up****	Increasing	✓	
Centroid Y when moving the light **down****	Decreasing	✓	
Centroid X when placing the light close to the camera boresight	Close to zero	✓	
Centroid X when moving the light to your **right****	Increasing	✓	
Centroid X when moving the light to your **left****	Decreasing	✓	

* If ***Sun is Above Local Horizon*** is **not** checked the *CubeADCS* expects to be in the eclipse part of its orbit according to the Unix time (or when ***Capture Status*** reads ***CaptureStartup***). This means the CubeACP will **not** sample the raw CubeSense outputs. If this happens change the *CubeACP*'s Unix time to "move" the satellite out of eclipse. This is done at *CubeACP* → *Standard* → *Satellite State* → *Current Unix Time*. (Normal flight software is used for Health Check).

** When looking at the lens from the front with the camera pins below the lens. Refer to the Appendix A at the end of this document for more detail on the CubeADCS' axes.

- While keeping the light in the field of view of the sun sensor, navigate to *Adcs 3-Axis* → *Save Image* block and Select *Cam1* in the drop-down menu next to *Camera Select*. The *Image size* drop-down menu can be any value, but not selecting *Size0* will reduce the downloading time by lowering the image quality (*Size3* recommended). Capture the image by sending the command by clicking on the green arrow. The camera will capture an image after a delay of 3 seconds. Continue to hold the light in front of the camera for this duration.
- Navigate to *Adcs 3-Axis* → *Status of Image Capture and Save Operation* box. Refresh the box. The *Percentage Complete* will increase slowly, which indicates the process of the image being saved to the SD card from CubeSense's memory.
- Once the *Percentage Complete* reaches 100%, navigate to the *File download* tab.
- Click on the refresh icon in the *Remote File System* block.

Signature of tester(s): H Wessels & C Groenewald

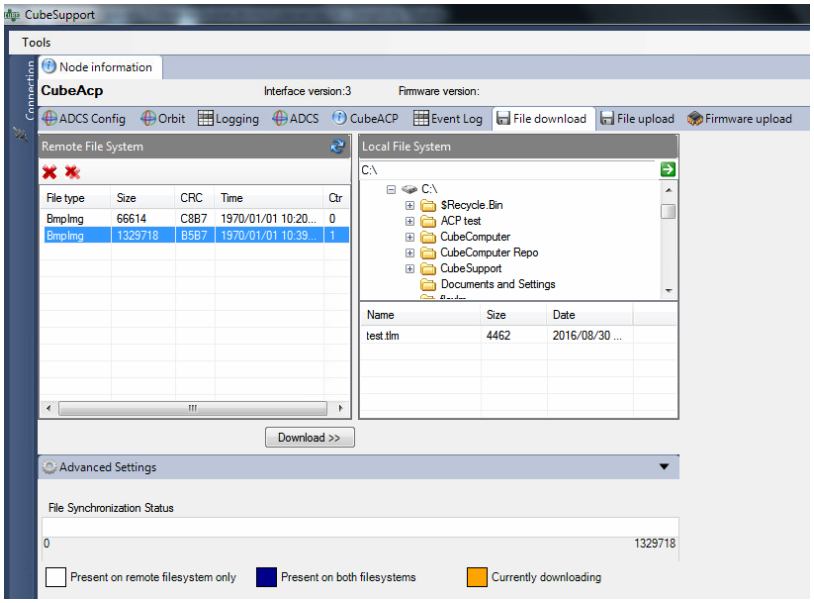


Figure 9 – *File download* tab

- Click on the *Bmp.Img* file at the end of the list. Once the file is selected the File Synchronization total size will change to the file size.
- Select a destination path in the Local File System and click the download button. A pop-up menu will appear where a location and file name can be specified, after which the download will start and the *File Synchronization Status* load bar will progress.

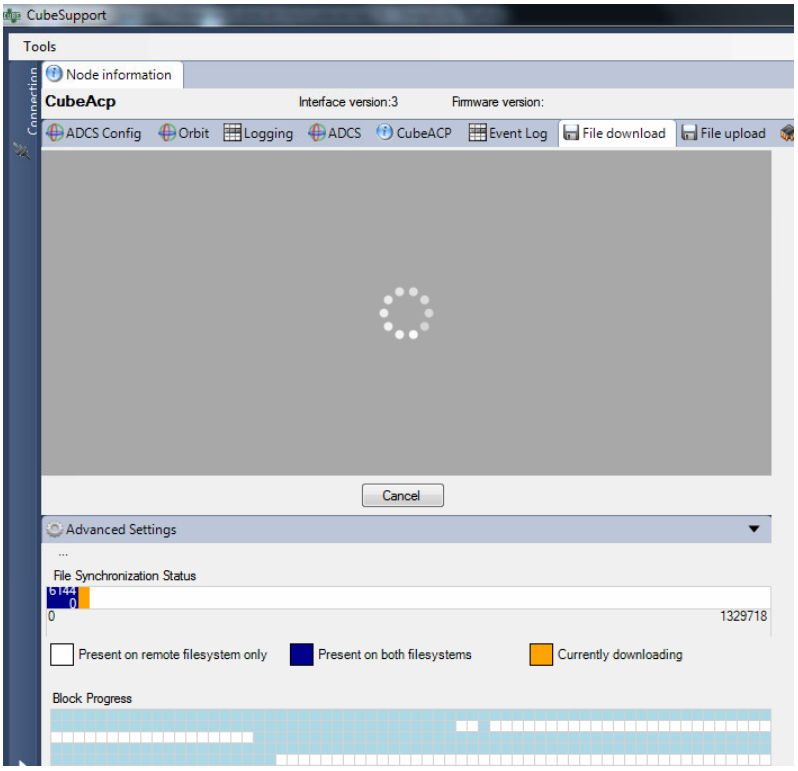


Figure 10 – Downloading a file

Signature of tester(s): H Wessels E C Groenewald

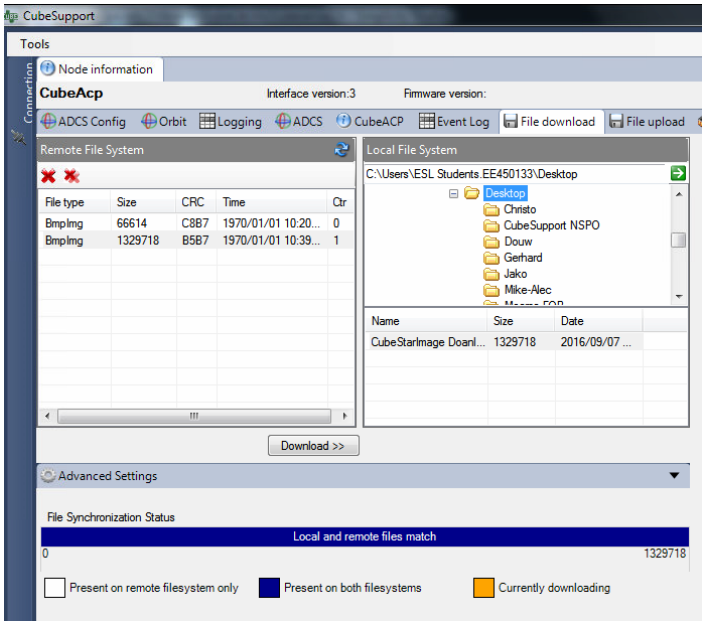


Figure 11 – File download complete

- Verify that the light source is clearly visible in the image (large and round for a Nadir sensor, or a small spot for Sun sensor).
- Put the **Cam1** camera's **lens cap** back **on**.
- Take **off** the **Cam2** camera's **lens cap**.
- Navigate back to the *ADCS* tab.
- Verify the following from the *Adcs 3-Axis → Raw Sensor Measurements → Raw Cam2* box by testing the sensor with a light source (a dark environment will prevent false detections). If Cam1 is a **Nadir** sensor then a **large** light source should be used (e.g. a desk lamp), or if Cam1 is a **Sun** sensor then a **small** light source should be used (e.g. narrow beam flash light). Vary the distance between the light source and the sensor until consistent measurements are observed (normally ±150mm). If difficulties are experienced with the Nadir sensor then the light source can be covered with white paper/cloth to create a more uniform light source. Finally, if no results are obtained for the Nadir or Sun sensors the exposure value can be adjusted.

Test / Task	Expected Result	Observed Result	User Observed Results
ADCS 3-Axis → Raw Sensor Measurements → Raw Cam2 Sensor			
Detection Result	DetectSuccess	✓	
Capture Status*	CaptureSuccessOwn	✓	
Centroid Y when placing the light close to the camera boresight	Close to zero	✓	

Signature of tester(s): H Wessels & C Groenewald

Centroid Y when moving the light **up****	Increasing	✓	
Centroid Y when moving the light **down****	Decreasing	✓	
Centroid X when placing the light close to the camera boresight	Close to zero	✓	
Centroid X when moving the light to your **right****	Increasing	✓	
Centroid X when moving the light to your **left****	Decreasing	✓	

* If ***Sun is Above Local Horizon*** is **not** checked the *CubeADCS* expects to be in the eclipse part of its orbit according to the Unix time (or when ***Capture Status*** reads ***CaptureStartup***). This means the CubeACP will **not** sample the raw CubeSense outputs. If this happens change the *CubeACP*'s Unix time to "move" the satellite out of eclipse. This is done at *CubeACP* → *Standard* → *Satellite State* → *Current Unix Time*. (Normal flight software is used for Health Check).

** When looking at the lens from the front with the camera pins below the lens. Refer to the Appendix A at the end of this document for more detail on the CubeADCS' axes.

- Follow the previous steps again to download a Cam2 camera image by selecting *Cam2* in the drop-down list. Remember to keep the light source in the field of view of the camera for the 3 seconds of image capture.
- Verify that the light source is clearly visible in the image (large and round for a Nadir sensor, or a small spot for Sun sensor).
- Put the **Cam2** sensor's **lens cap** back **on**.
- Switch **off CubeSense** in the *ADCS Power Control* box.

Signature of tester(s): H Wessels & C Groenewald

5. CubeControl

5.1 CubeControl Signal MCU

Follow the instructions below to perform the CubeControl Signal MCU health check:

- Switch **on CubeControl Signal MCU** by selecting *PowOn* in the drop-down menu next to *CubeControl Signal Power Selection* in the *ADCS Power Control* box and transmit the command by clicking on the green arrow.
- Verify the following under the *ADCS* tab:

Test / Task	Expected Result	Observed Result	User Observed Results
ADCS 3-Axis → ADCS state → Current ADCS State			
ADCS Run Mode	AdcsEnabled	✓	
Attitude Estimation Mode	EstNone	✓	
Control Mode	ConNone	✓	
CubeControl Signal Enabled	Checked	✓	
All other checkboxes*	Unchecked	✓	
ADCS 3-Axis → ADCS Power → CubeControl Current Measurements			
CubeControl 3V3 Current	30 ± 10 mA	29.29 mA ✓	
CubeControl 5V Current	5 ± 4 mA	3.42 mA ✓	
CubeControl Vbat Current	< 4 mA	0.98 mA ✓	
ADCS 3-Axis → ADCS Power → ADCS Temperatures			
Magnetometer Temperature	Near room temp	24.5 °C ✓	
MCU Temperature	Near room temp	27 °C ✓	
ADCS 3-Axis → Raw Sensor Measurements → Raw Css1 to Css6			
CSS1	8 ± 5	✓	
CSS2	8 ± 5	✓	
CSS3	8 ± 5	✓	
CSS4	8 ± 5	✓	
CSS5	8 ± 5	✓	
CSS6	8 ± 5	✓	
ADCS 3-Axis → Raw Sensor Measurements → Raw Css7 to Css10			
CSS7	8 ± 5	✓	
CSS8	8 ± 5	✓	

Signature of tester(s): H Wessels & C Groenewald

CSS9	8 ± 5	✓	
CSS10	8 ± 5	✓	

* Except for the aforementioned error flags and *Sun is Above Local Horizon*.

- Expose the coarse sun sensors to a bright light, one by one.
- Verify the following:

Test / Task	Expected Result	Observed Result	User Observed Results
ADCS 3-Axis → Raw Sensor Measurements → Raw Css1 to Css10			
Raw measurements when **exposed** to light	> 50 (each channel)	✓	

- Go to *ADCS 3-Axis → ADCS state → Current ADCS State* and ensure that the *Magnetometer Range Error* is **not** checked. If it is checked the magnetometer is unable to measure a sufficient/overpowering magnetic field. This can be solved by placing the magnetometers away from motors, power supplies, large ferromagnetic objects, *etc.* or ensuring no contact to an anti-static mat.
- Familiarise the **axes** of the magnetometer, as shown at the end of this document in Appendix A.
- Navigate to *Adcs 3-Axis - Raw Sensor Measurements* and verify the operation of the magnetometers by using the *Raw Magnetometer*. Choose an axis on the magnetometer and point it in the positive direction of the magnetic field lines (north) to align the axis with the magnetic vector. Now rotate the magnetometer around this axis. The chosen axis must remain positive while the other two axes will both go negative and positive though the rotation. Repeat this for all three axes to verify polarities.

Test / Task	Expected Result	Observed Result	User Observed Results
ADCS 3-Axis → Raw Sensor Measurements			
Raw Magnetometer shows varying values in X, Y and Z directions correctly	✓	✓	

- Navigate to *Adcs 3-Axis – Adcs Measurements → Magnetic Field vector*. Rotate the magnetometer and verify that the magnetic field vector displays both positive and negative in X, Y, and Z directions correctly. Fill the following table accordingly:

Test / Task	Expected Result	Observed Result	User Observed Results

Signature of tester(s): H Wessels & C Groenewald

ADCS 3-Axis → Adcs Measurements → Magnetic Field Vector			
Magnetic Field can measure both positive and negative in X, Y and Z directions	✓	✓	

Test the magnetorquer rods and coil by following the procedure below:

- Navigate to the *Adcs 3-Axis-Actuator-Commands* → *Set Magnetorquer Output* box. Command the magnetorquer coil (X-axis) to maximum positive direction by setting the slider bar all the way to the right next to *Command X Magnetorquer* and send the command by clicking on the green arrow.
- Confirm the current measurement and the direction of magnetic field in the table below. The direction can be confirmed by placing a compass directly in line with the magnetorquer and observing the field direction or using an external magnetometer. Note that the magnetorquer pulses on for a maximum of 0.8 seconds and then switches off.
- Change the command to maximum negative and confirm the current and direction again.
- Command the magnetorquer to 0 to turn off the magnetorquer.
- Repeat these steps for the Y and Z magnetorquer rods and record the required values below.

Test / Task	Expected Result	Observed Result	User Observed Results
ADCS 3-Axis - ADCS Power → ADCS Misc/CubeControl Current Measurements			
(X) Magnetorquer Current	120 ± 20 mA	133.7 mA ✓	
X Magnetorquer direction of magnetic field with max positive command	+X	✓	
X Magnetorquer direction of magnetic field with max negative command	-X	✓	
(Y) Magnetorquer Current	65 ± 10 mA	66.6 mA ✓	
Y Magnetorquer direction of magnetic field with max positive command	+Y	✓	
Y Magnetorquer direction of magnetic field with max negative command	-Y	✓	

Signature of tester(s): H Wessels & C Groenewald

(Z) Magnetorquer Current	65 ± 10 mA	65.7 mA ✓	
Z Magnetorquer direction of magnetic field with max positive command	+Z	✓	
Z Magnetorquer direction of magnetic field with max negative command	-Z	✓	

- Ensure that all the magnetorquers are set to 0 (turned off) before continuing the test.

5.2 CubeControl Motor and Signal MCU

Follow the instructions below to perform the CubeControl MCU health check:

- Switch **on** CubeControl's **Motor MCU** by selecting *PowOn* in the drop-down menu next to *CubeControl Signal Power Selection* in the *ADCS Power Control* box and transmit the command by clicking on the green arrow. (*CubeControl Signal Power Selection* must remain enabled).
- Verify the following:

Test / Task	Expected Result	Observed Result	User Observed Results
ADCS 3-Axis → ADCS state → Current ADCS State			
ADCS Run Mode	AdcsEnabled	✓	
Attitude Estimation Mode	EstNone	✓	
Control Mode	ConNone	✓	
CubeControl Signal Enabled	Checked	✓	
CubeControl Motor Enabled	Checked	✓	
All other checkboxes*	Unchecked	✓	
ADCS 3-Axis → ADCS Power → CubeControl Current Measurements			
CubeControl 3V3 Current	65 ± 15 mA	60.5 mA ✓	
CubeControl 5V Current	5 ± 4 mA	3.42 mA ✓	
CubeControl Vbat Current	< 4 mA	0.98 mA ✓	
ADCS 3-Axis → ADCS Power → ADCS Temperatures			
Magnetometer Temperature	Near room temp	24.8 °C ✓	
MCU Temperature	Near room temp	27 °C ✓	
Adcs 3-Axis → ADCS Power → Rate sensor temperatures			
X-Rate Sensor Temperature	Near room temp	21 °C ✓	

Signature of tester(s): H Wessels & C Groenewald

Y-Rate Sensor Temperature	Near room temp	25 °C ✓	
Z-Rate Sensor Temperature	Near room temp	21 °C ✓	

* Except for the aforementioned error flags and *Sun is Above Local Horizon*.

- Rotate the magnetometer and confirm that the values in the *Raw Magnetometer* box change. Ensure that the X, Y and Z axes display both positive and negative values.

Test / Task	Expected Result	Observed Result	User Observed Results
ADCS 3-Axis → Raw Sensor Measurements			
Raw Max X, Mag Y and Mag Z measurements can measure both positive and negative	✓	✓	

- Switch **off** CubeControl's **Signal MCU** by selecting *PowOff* in the drop-down menu next to *CubeControl Signal Power Selection* in the *ADCS Power Control* box and transmit the command by clicking on the green arrow.
- Only the CubeControl Motor MCU should now be on.

5.3 CubeControl Motor MCU

- Verify the following:

Test / Task	Expected Result	Observed Result	User Observed Results
ADCS 3-Axis → ADCS state → Current ADCS State			
ADCS Run Mode	AdcsEnabled	✓	
Attitude Estimation Mode	EstNone	✓	
Control Mode	ConNone	✓	
CubeControl Motor Enabled	Checked	✓	
All other checkboxes*	Unchecked	✓	
ADCS 3-Axis → ADCS Power → Rate sensor temperatures			
X-Rate Sensor Temperature	Near room temp	18 °C ✓	
Y-Rate Sensor Temperature	Near room temp	23 °C ✓	
Z-Rate Sensor Temperature	Near room temp + 10°C	19 °C ✓	
ADCS 3-Axis - ADCS Measurements → Rate Sensor Rates			

Signature of tester(s): H Wessels & C Groenewald

X-rate can be positive or negative (tilt the unit)	✓	✓	
Y-rate can be positive or negative (tilt the unit)	✓	✓	
Z-rate can be positive or negative (tilt the unit)	✓	✓	

* Except for the aforementioned error flags and *Sun is Above Local Horizon*.

- Rotate the magnetometer and confirm that the values in the *Raw Magnetometer* box change. Ensure that the X, Y and Z axes display both positive and negative values.

Test / Task	Expected Result	Observed Result	User Observed Results
ADCS 3-Axis → Raw Sensor Measurements			
Raw Magnetometer shows varying values in X, Y and Z directions correctly	✓	✓	

Test the magnetorquer rods and coil by following the procedure below:

- Navigate to the *Adcs 3-Axis-Actuator-Commands → Set Magnetorquer Output* box. Command the magnetorquer coil (X-axis) to maximum positive direction by setting the slider bar all the way to the right next to *Command X Magnetorquer* and send the command by clicking on the green arrow.
- Confirm the current measurement and the direction of magnetic field in the table below. The direction can be confirmed by placing a compass directly in line with the magnetorquer and observing the field direction or using an external magnetometer. Note that the magnetorquer pulses on for a maximum of 0.8 seconds and then switches off.
- Change the command to maximum negative and confirm the current and direction again.
- Command the magnetorquer to 0 to turn off the magnetorquer.
- Repeat these steps for the Y and Z magnetorquer rods and record the required values below.

Test / Task	Expected Result	Observed Result	User Observed Results
ADCS 3-Axis → ADCS Power → ADCS Misc/CubeControl Current Measurements			
(X) Magnetorquer Current	120 ± 20 mA	132.5 mA ✓	

Signature of tester(s): H Wessels & C Groenewald

X Magnetorquer direction of magnetic field with max positive command	+X	✓	
X Magnetorquer direction of magnetic field with max negative command	-X	✓	
(Y) Magnetorquer Current	65 ± 10 mA	66 mA ✓	
Y Magnetorquer direction of magnetic field with max positive command	+Y	✓	
Y Magnetorquer direction of magnetic field with max negative command	-Y	✓	
(Z) Magnetorquer Current	65 ± 10 mA	65.6mA ✓	
Z Magnetorquer direction of magnetic field with max positive command	+Z	✓	
Z Magnetorquer direction of magnetic field with max negative command	-Z	✓	

- Ensure that all the magnetorquers are set to 0 power (turned off) before continuing the test.

5.4 CubeControl Motor Health check

This section is only applicable to the Y-Momentum ADCS where the y-momentum wheel is mounted on CubeControl.

- Switch **on Motor Power** by selecting *PowOn* in the drop-down menu next to *Motor Power Selection* in the *ADCS Power Control* box and transmit the command by clicking on the green arrow. (CubeControl Motor MCU must remain powered on)
- Verify the following:

Test / Task	Expected Result	Observed Result	User Observed Results
ADCS 3-Axis → ADCS state → Current ADCS State			
ADCS Run Mode	AdcsEnabled	✓	
Attitude Estimation Mode	EstNone	✓	
Control Mode	ConNone	✓	
CubeControl Motor Enabled	Checked	✓	

Signature of tester(s): H Wessels & C Groenewald

Motor Driver Enabled	Checked	✓	
All other checkboxes*	Unchecked	✓	

* Except for the aforementioned error flags and *Sun is Above Local Horizon*.

- Navigate to *Adcs 3-Axis – Actuator commands*, and in the *Set Wheel Speed* box, set the *Commanded Y speed* to 4000rpm (the axis of the wheel can later be changed in the *ADCS Config* tab).
- Verify the following after 20 seconds:

Test / Task	Expected Result	Observed Result	User Observed Results
ADCS 3-Axis → ADCS Measurements → Wheel Speed			
Y Wheel Speed	4000 ± 10 rpm	✓	
ADCS 3-Axis → ADCS Power → Wheel Currents			
Wheel2Current	15 ± 9 mA	16.16 mA ✓	

- Command the wheel speed to -2000 RPM.
- Verify the following after 20 seconds:

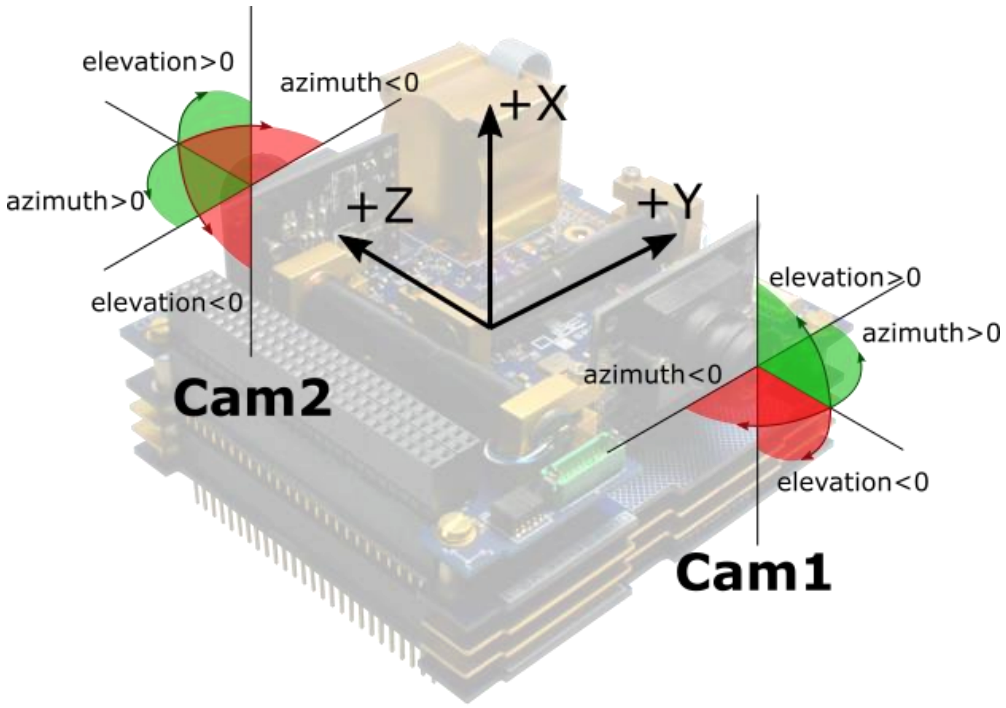
Test / Task	Expected Result	Observed Result	User Observed Results
ADCS 3-Axis → ADCS Measurements → Wheel Speed			
Y Wheel Speed	-2000 ± 10 rpm	✓	
ADCS 3-Axis → ADCS Power → Wheel Currents			
Wheel2Current	9 ± 9 mA	10.5 mA ✓	

- Command the wheel speed to 0 RPM
- Verify the following after 20 seconds:

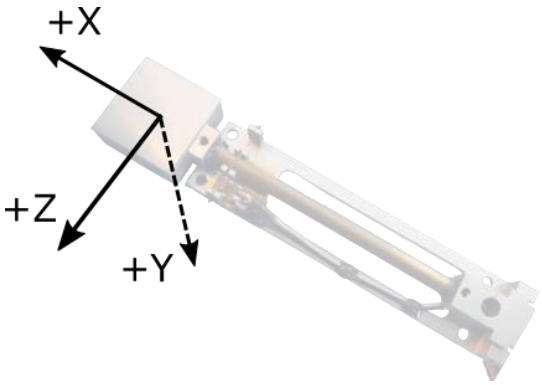
Test / Task	Expected Result	Observed Result	User Observed Results
ADCS 3-Axis → ADCS Measurements → Wheel Speed			
Y Wheel Speed	0	✓	
ADCS 3-Axis → ADCS Power → Wheel Currents			
Wheel2Current	7 ± 9 mA	3.79 mA ✓	

Signature of tester(s): H Wessels & C Groenewald

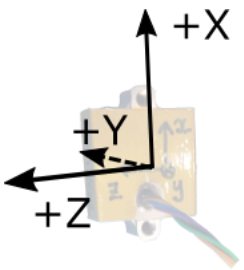
6. Appendix A: CubeADCS Axes



CubeADCS and CubeSense Cameras



Main Magnetometer



Redundant Magnetometer

Signature of tester(s): H Wessels & C Groenewald

7. Document Version History

Version	Responsible person(s)	Pages	Date	Description of change
3.0	MK	ALL	20/03/2017	V3 First draft
3.02	CJG	ALL	15/05/2017	Added client column
3.03	CJG	29-31	06/06/2017	Updated the CubeStar Health Check.
3.04	CJG	8, 17, 18-19	15/06/2017	Changed wait time for ACP boot to 10s. Updated magnetometer test description. Removed unnecessary current measurements.
3.05	CJG	9	22/06/2017	Updated the firmware version
3.06	CJG	All	18/07/2017	Updated and added bootloader section.
3.07	CJG	ALL	03/08/2017	Added y-Momentum ADCS Wheel Test
3.08	HW	7	19/01/2018	Improved readability
3.09	CJG	12	15/02/2018	Updated the ACP Image
3.10	HW	CubeSense	26/02/2018	Changed naming of Nadir/Sun to Cam1/Cam2, and improved readability.
3.11	HW	CubeControl	27/02/2018	Improved magnetometer checks, measurement tolerances, and various small things.
3.12	HW	CubeSense	07/03/2018	Added rough check for CubeSense camera boresight verification
3.13	HW	CubeSense CubeStar CubeADCS Axes	03/04/2018	Improved CubeSense download readability Updated CubeStar Health Check Improved CubeADCS Axes Appendix
3.14	HW	CubeStar CubeSense	06/04/2018	Updated CubeStar Detection timing range Updated eclipse solution description
3.15	HW	CubeControl All	19/04/2018	Fixed Momentum wheel tests Combined 3-Axis and Y-Mom Documents