CUBESPACE

CubeSense Earth Generation 2

Interface Control Document (ICD)

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VERSION	AUTHORS	DATE	DESCRIPTION
A	C. Leibbrandt	15/06/2023	First draft release
B	R. van Wyk	20/07/2023	Review and updates
1.00	C. Leibbrandt	24/07/2023	First published version

Reference Documents

The following documents are referenced in this document.

[1] CS-DEV.PD.CI-01 CubeSense Earth Product Description Ver.1.00 or later

[2] CS-DEV.UM.CI-01 CubeSense Earth User Manual Ver.1.00 or later

List of Acronyms/Abbreviations

ACP	ADCS Control Program
ADCS	Attitude Determination and Control System
CAN	Controller Area Network
COM	Centre of Mass
COTS	Commercial Off The Shelf
CSS	Coarse Sun Sensor
CVCM	Collected Volatile Condensable Materials
DUT	Device Under Test
EDAC	Error Detection and Correction
EHS	Earth Horizon Sensor
EM	Engineering Model
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
FDIR	Fault Detection, Isolation, and Recovery
FM	Flight Model
FSS	Fine Sun Sensor
GID	Global Identification
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GYR	Gyroscope
I2C	Inter-Integrated Circuit
ID	Identification
LTDN	Local Time of Descending Node
LEO	Low Earth Orbit
MCU	Microcontroller Unit
MEMS	Microelectromechanical System
MTM	Magnetometer
MTQ	Magnetorquer
NDA	Non-Disclosure Agreement
OBC	On-board Computer
PCB	Printed Circuit Board

RTC	Real-Time Clock
RWA	Reaction Wheel Assembly
RW	Reaction Wheel
SBC	Satellite Body Coordinate
SOFIA	Software Framework for Integrated ADCS
SPI	Serial Peripheral Interface
SRAM	Static Random-Access Memory
SSP	Sub-Satellite Point
STR	Star Tracker
TC	Telecommand
TCTLM	Telecommand and Telemetry (protocol)
TID	Total Ionizing Dose
TLM	Telemetry
TML	Total Mass Loss
UART	Universal Asynchronous Receiver/Transmitter

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1 Introduction

This document is written with the assumption that the reader is familiar with the CubeSense Earth as described in [1]. The purpose of this document is to provide Interface Control Document (ICD) related information about CubeSense Earth.

This version of ICD applies to the CubeSense Earth hardware versions as stated in Table 1 below.

Table 1: Document Applicability

CUBEPRODUCT	VERSION	NOTES
CubeSense Earth	M2.0E1.3	

2 Electrical Interface

This chapter describes the electrical interfaces of the CubeSense Earth. This includes:

1. Communication interfaces
2. Power interfaces and expected power levels, and
3. Harness details

2.1 CubeSense Earth Communication interface(s)

This section describes the configuration and characteristics of the following communication interfaces to the CubeSense Earth.

- CAN
- UART
- RS485 / RS422 (custom option)
- I2C (custom option)

2.1.1 CAN Characteristics

The characteristics of the CubeSense Earth CAN bus are given in Table 2.

Table 2: CAN bus characteristics for CubeSense Earth

PARAMETER	VALUE
Supported CAN standard	V2.0B
Supported bitrate(s)	1 Mbit/s
Supported protocol(s)	CubeSpace CAN Protocol, CubeSat Space Protocol (CSP)

2.1.2 UART characteristics

The characteristics of the CubeSense Earth UART interface are given in Table 3.

Table 3: UART characteristics for CubeSense Earth

PARAMETER	VALUE
Maximum supported Baud rate	921600 (configurable)
Data bits	8
Parity	None
Stop bits	1

2.1.3 RS485 / RS422 characteristics (custom option)

RS485 / RS422 communication with the CubeSense Earth is provided as a custom option and must specifically be specified by the client at the time of order placement. The UART characteristics of the RS485 / RS422 interface are the same as in Table 3. Additional RS485 / RS422 characteristics are given in Table 4

Table 4: RS485 / RS422 characteristics for CubeSense Earth

PARAMETER	VALUE
Data Enable (DE) polarity	High

2.1.4 I2C Characteristics (custom option)

I2C communication with CubeSense Earth is provided as a custom option and must specifically be specified by the client at the time of order placement. The CubeSense Earth is always configured as a slave on the I2C bus and cannot initiate communications by itself. It is important to note that the master that communicates with the CubeSense Earth CubeComputer must support clock stretching. The relevant I2C characteristics for the CubeSense Earth are given in Table 5.

Table 5: I2C bus characteristics for CubeSense Earth

PARAMETER	VALUE
Maximum supported bitrate	1 Mbit/s (I2C Fast Mode Plus)
Addressing mode	7-bit configurable slave address
Clock stretching	Yes (master must support clock stretching)
Repeated-start support	Not supported

2.2 CubeSense Earth Power supply

Table 6 below summarizes the power supply voltages to be supplied by the client ADCS / OBC.

Table 6: CubeSense Earth external power supply requirements

	CUBESENSE EARTH
EXTERNAL POWER	
Supply voltage [V]	3.3
Peak power [mW]	280
Average power [mW]	200

2.2.1 Power consumption: 3.3V rail

The CubeSense Earth has an average power consumption on the 3.3 V line independent of the satellite's size or ADCS modes used. This is because the basic digital circuit is designed to be common amongst the CubeProducts, and all are powered from 3.3V.

The average and maximum power consumption and the peak inrush current and duration on the 3.3 V line for the CubeSense Earth are shown in Table 7.

Table 7: CubeSense Earth Average power consumption and inrush current on 3.3 V line

SUBSYSTEM	3.3 V RAIL					NOTES
	Avg Current (mA)	Avg Power (mW)	Max Current (mA)	Max Power (mW)	Inrush (mA – µs)	
CubeSense Earth	61	200	85	280	221-50	Estimated for 1 Hz detection.

2.2.2 Power Protection

CubeSense Earth Power Protection is included. Specifically, if the 3V3 power supplied externally falls outside the 2.5V – 4.0V range, the CubeSense Earth will automatically switch off.

It is however expected that the user follows the specifications provided for the CubeSense Earth system as specified in this document. Whenever any input or interface is used out of specified ranges, CubeSpace cannot ensure that the CubeSense Earth will function as intended.

Note that there is no protection against overvoltage on the $V_{Battery}$ bus line. A voltage input above 20V will cause damage.

2.2.2.1 CubeSense Earth Enable line.

The CubeSense Earth implements an externally controlled/controllable Enable line. The Enable line should be controlled by the client ADCS or OBC. The CubeSense Earth is enabled if the Enable line is active (high). If the CubeSense Earth Enable line is pulled low, the CubeSense Earth will be disabled.

2.2.2.2 CubeSense Earth 3V3 undervoltage protection needed

The client ADCS / OBC should monitor the 3V3 rail voltage level and ensure that it is above the minimum threshold voltage before switching on the 3V3 to the CubeSense Earth. This will ensure protection of the CubeSense Earth from undervoltage conditions and helps protect memory and other sensitive circuits on the CubeSense Earth.

It is suggested that the client ADCS / OBC should provide current limiting for the 3V3 power supply to the CubeSense Earth and should also allow for latching off during a fault to protect against hard latch-up events.

The above functionality is available on the CubeADCS CubeComputer. If the CubeSense Earth is connected to the client ADCS / OBC, similar protection is suggested.

2.2.2.3 CubeSense Earth 3V3 power switch

The CubeSense Earth implements an input power switch. It is enabled by pulling the Enable line high for the CubeSense Earth. This switch allows the client ADCS / OBC to isolate it from the 3V3 power rail. The CubeSense Earth power switch also provides a current limit (400mA) feature to protect against hard-latch-up events. It also has overvoltage protection set to trigger upwards of 3.9V (depending on thermal conditions).

2.3 Harnesses

The CubeSense Earth is designed to connect to the CubeComputer (or the client ADCS / OBC) via a dedicated harness with Molex Micro-Lock plus housings crimped onto each end.

The wire length between the housings can be specified from a selection of standard lengths. The client can specify the desired length when the order for the CubeSense Earth is placed.

If the client needs a different connector between the CubeSense Earth and the client ADCS / OBC, CubeSpace suggests that the standard CubeSense Earth harness is supplied and the ADCS / OBC side connector be replaced by the client with his desired connector – CubeSpace tries to focus on mass production of harnesses with a limited number of connector housing supported to ensure reliability and repeatability. “Custom” / non-standard CubeSpace connectors are avoided if possible.

The wire used has a PTFE insulation which is low outgassing.

The CubeSense Earth standard harness characteristics are described in Table 8 below. In Table 8, Housing 1 and terminal 1 mate with the Client ADCS / OBC, and Housing 2 and terminal 2 mate with the CubeSense Earth itself.

Table 8: CubeSense Earth Harness characteristics

Harness	Housing 1 mass (mg)	Terminal 1 mass (mg)	Wire Gauge (AWG)	Wire mass (kg/km)	Housing 2 mass (mg)	Terminal 2 mass (mg)	pins	Total[1] Mass
CubeSense Earth Sensor	229.64	35.434	26	1.96	198.8	35.434	8	

2.3.1 Harness Header on CubeSense Earth

A 10-pin Molex 5055671081 right-angle header provides the electrical interface to the CubeSense Earth.

Table 9: CubeSense Earth Interface details

CUBESENSE EARTH INTERFACE DETAILS				
Header Type:		Molex 5055671081		
Number of pins		10		
Mating Housing		Molex 5055651001		
Housing Terminal		5037650098		
CUBESENSE EARTH HEADER PIN DEFINITIONS				
Pin #	Pin Name	Pin Description	IO Type	Voltage range [V]
1	BOOT	Active High boot line. Leave unconnected if unused.	Input	-0.3 to 3.4 $V_{low} < 0.5$ $V_{high} > 2.6$
2	GND	Power ground of CubeWheel electronics	Power	0
3	3V3	Supply voltage for the digital electronics	Power	3.2 to 3.4
4	UART_TX (RS485_A)[1]	UART Data Transmit of MCU.	Output	-0.5 to 3.4
5	CAN_P	High-level CAN bus line	Differential	-3.4 to 3.4
6	CAN_N	Low-level CAN bus line	Differential	-3.4 to 3.4
7	UART_RX (RS485_B)[1]	UART Data Receive of MCU. Pull high if unused.	Input	-0.5 to 3.4

[1] Total mass of the harness depends on the harness length. The total mass can thus be self-calculated using the wire mass (in kg/km) for the specified / selected harness lengths.

CUBESENSE EARTH INTERFACE DETAILS				
8	GND	Power ground of electronics	Power	0
9	GND	Power ground of CubeWheel electronics	Power	0
10	Enable	Active high enable	Input	-0.3 to 3.4 $V_{low} < 0.95$ $V_{high} > 1.05$

[1]CubeSense Earth can be configured for RS485 or UART

3 Mechanical Interface

This chapter describes the mechanical interface of the CubeSense Earth. This includes:

1. The outer dimensions of the CubeSense Earth,
2. The mounting definition and specifics (hole pattern and if the mounting of the component affects its performance),
3. Mass, Centre of Mass, and Inertia,
4. Coordinate System.

PLEASE NOTE: The dimensions given in this section are **indicative only**. The mechanical CAD files received from CubeSpace should be treated as the source of truth.

3.1 CubeSense Earth

The CubeSense Earth sensor is fully enclosed in an aluminium housing manufactured from aluminium 6082-T6 treated with a chromate conversion coating (Alodine). A Molex Micro-lock connector is used to interface with the sensor, as indicated in Figure 1

3.1.1 Outer Dimensions

The overall dimensions of the CubeSense Earth are shown in Figure 1

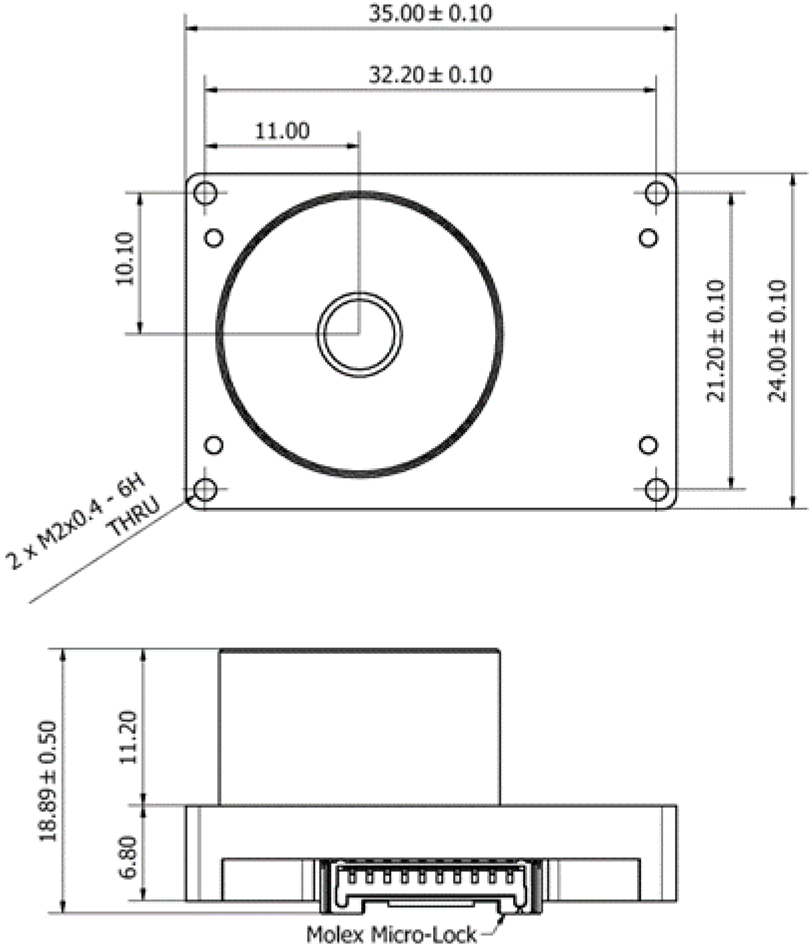

Figure 1: Indicative dimensions of the CubeSense Earth sensor

3.1.2 Mounting definition

The CubeSense Earth should ideally be mounted so that the earth horizon will be in the centre of the camera field of view for the satellite's nominal flight orientation. The sensor will then be able to give valid measurements at higher elevations and roll rotations. The detection field of view is 90 degrees horizontal, 80 degrees vertical and 90 degrees diagonal. See Figure 2 for the CubeSense Earth axis definitions. The exclusion field of view, which should be kept clear of obstructions from the satellite, is 90 degrees vertical and 120 degrees horizontal. If this exclusion area cannot be accommodated, contact CubeSpace for arrangements to implement special masking software to mitigate negative effects.

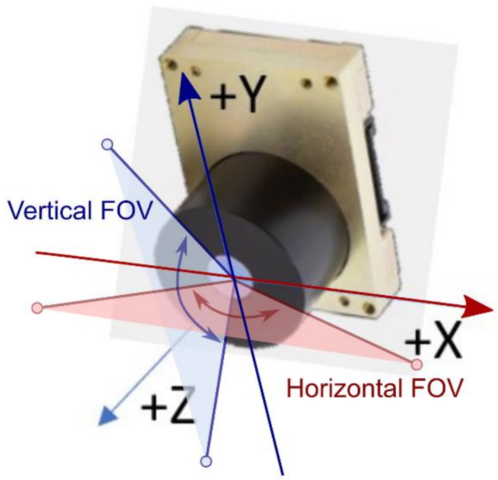

Figure 2: CubeSense Earth Axis definition

3.1.3 Mass, COM and Inertia

The CubeSense Earth has a mass of 18.0 g ± 5 %. Figure 3 displays the COM position.

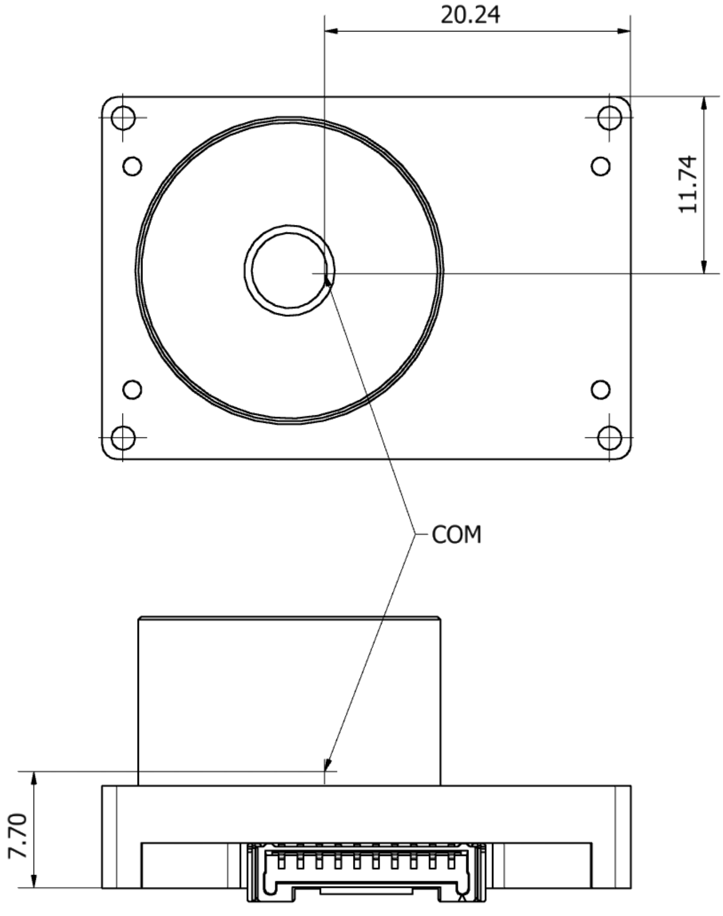

Figure 3: COM position of CubeSense Earth

The moments of inertia of the CubeSense Earth about the COM position are presented in Table 10, the axes reference for the inertias provided is shown in Figure 2.

Table 10: CubeSense Earth Moments of Inertia (MOI)

AXIS	VALUE
I_{xx} (gmm^2)	1081 ± 10 %
I_{yy} (gmm^2)	852 ± 10 %
I_{zz} (gmm^2)	1000 ± 10 %

3.1.4 Measurement Coordinate System Definition

Refer to Figure 2 for the coordinate system definition of the CubeSense Earth.

4 CubeSense Earth Mass

Table 11 details the mass of the CubeSense Earth.

Table 11: CubeSense Earth mass

CUBESENSE EARTH	VARIANT/MODEL	MASS (G)[2]	NOTES
CubeSense Earth	NA	18	Measured

[2] This is the mass of the CubeProduct only and does not include any harnessing as these lengths can vary. Allow margin for the harness mass (refer section 2.3).

5 EMI / EMC

This chapter identifies all oscillators (potential RF emitters) used on the CubeSense Earth.

5.1 Potential RF emitter list

Table 12: CubeSense Earth Potential Emitters

CUBEPRODUCT	COMPONENT	EMITTER TYPE	FREQUENCY	FREQ. STABILITY
CubeSense Earth	Thermal sensor	SPI	2.4 MHz	± 50 ppm
	MCU	Crystal	24 MHz	± 50 ppm
	Comms UART	UART	0.92MHz	± 50 ppm
	Comms CAN	CAN	500 kHz	± 50 ppm

5.2 Minimising EMI / EMC effects

5.2.1 Grounding

The enclosure and mechanical parts of CubeSense Earth are connected to the electrical ground through a filter designed to minimise EMI, as illustrated by Figure 4, with “ADCS node 1” representing the CubeSense Earth. (Note that a generic CubeADCS diagram is shown to explain the grounding strategy followed, for consideration by the client). The enclosures of the [CubeADCS core stack] and the CubeSense Earth can be grounded by the user if desired.

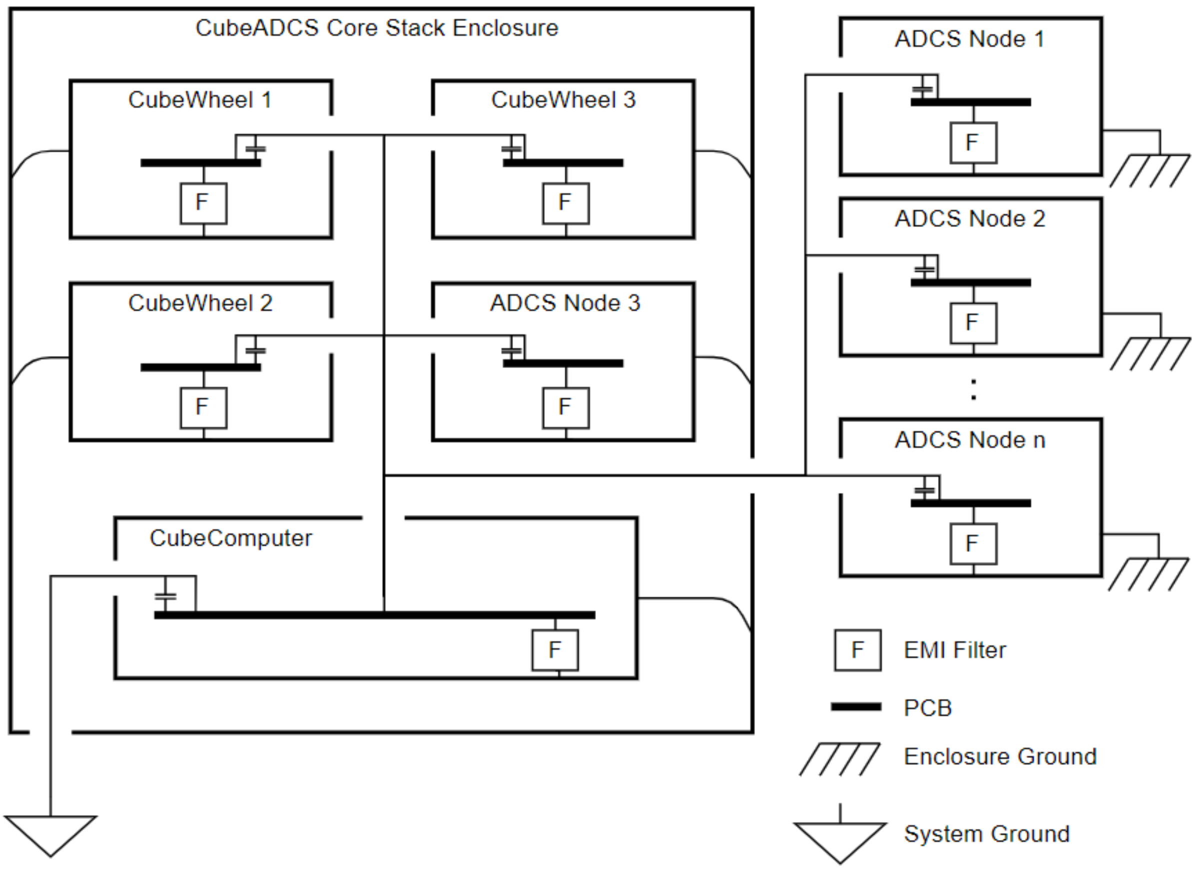

Figure 4: Generic Grounding diagram

The filter design consists of a high-value resistor in parallel with a low ESL capacitor. This dissipates high-frequency noise to ground and also conducts static buildup off of the enclosure. The commonly used alternative method where the enclosures are directly connected to the ground introduces the risk that shorts may occur during satellite integration.

In some cases a customer might require the enclosure of the CubeSense Earth to be completely isolated from the System Ground by removing the EMI filters completely. In such a case, it could be specified as a custom option when placing the order.

5.2.2 Shielding

Shielding of the CubeSense Earth electronics is accomplished by the mechanical (Faraday) enclosure. The enclosure makes contact with the chassis ground trace on each PCB. This chassis trace is connected to PCB ground through the filter discussed in the previous section.

5.2.3 Harness pairing of conductors and twisting.

The wires of the harnesses provided by CubeSpace for the CubeSense Earth form twisted pairs as indicated in Table 13 below.

Table 13: Twisted Wire Pairs on Harness

PIN 1	PIN 2	COMMENT
3V3	GND	
Enable	GND	
Boot	GND	
CANH	CANL	If CAN is used
RS485 A	RS485 B	If optional RS485 is used
UART Rx	GND	If UART is used
UART Tx	GND	If UART is used

Furthermore, the twisted wire pairs are braided/rolled to form the final harness. Figure 5 below shows an image of a final flight harness.

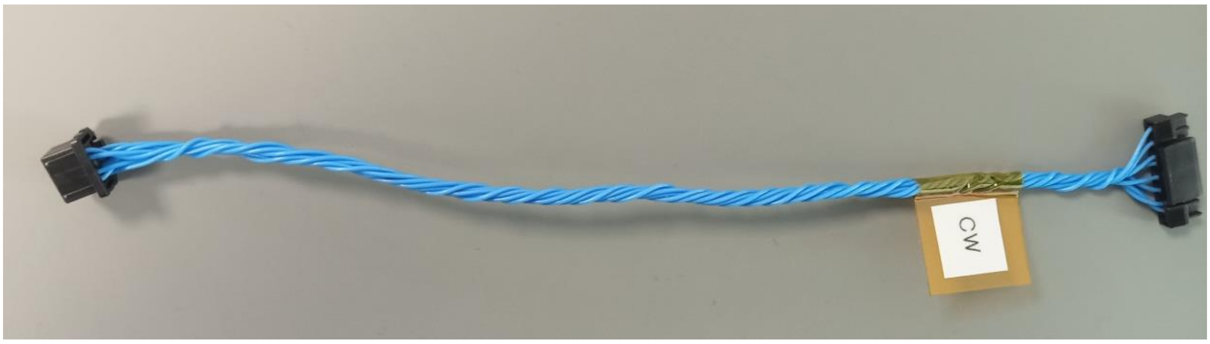

Figure 5: Flight harness example

5.2.4 Filtering and Suppression

The following noise filtering schemes are utilised on the CubeSense Earth:

a. All pins that are externally exposed through headers are filtered by way of 100pF decoupling to ground as shown in Figure 4.
b. LC filtering is done on the CubeComputer's external 5V and 3.3V power supply input lines.
    - For the standalone CubeSense Earth, the client is requested to consider implementing similar on the client ADCS / OBC side – details can be provided.
c. LC filtering is done on the CubeComputer's 5V and 3.3V supply lines to the various CubeProducts.
    - For the standalone CubeSense Earth, the client is requested to consider implementing similar on the client ADCS / OBC side – details can be provided.
d. Common-mode filtering is done on the CubeComputer's CAN communication interfaces (from the OBC, and to various CubeProducts).
    - For the standalone CubeSense Earth, the client is requested to consider implementing similar on the client ADCS / OBC side – details can be provided.
e. RC filtering is employed on the CAN, UART, and (optional) I2C communication interfaces to minimize spurious frequencies above 1 MHz.
f. The Boot- and Enable lines from the CubeComputer to the various CubeProducts employ LC filtering at the CubeConnect-level.
    - For the standalone CubeSense Earth, the client is requested to consider implementing similar on the client ADCS / OBC side – details can be provided.

6 Environmental Qualification

CubeSpace has recently completed a so-called "re-spin" of all generation 2 CubeProducts, including the CubeSense Earth. The re-spin effort entails minor design improvements across the board to improve lessons learnt during EMI/EMC characterisation sessions, to address minor layout optimisations that were identified and to address issues found on power regulation devices used on the CubeComputer whilst exposed to high TID radiation levels.

CubeSpace is currently in process of a full environmental re-qualification campaign of the re-spun versions of the generation 2 CubeProducts as they come off the production line. A completion date of mid-2023 is targeted. This chapter will then be updated accordingly documenting the formal qualification status of the CubeSense Earth.

6.1 Test approach outline

Environmental testing is done according to a "CubeSpace generation 2 Environmental Qualification plan".

The mentioned qualification plan contains detailed information and steps to be taken by the typical test engineer when qualifying the CubeSense Earth, together with the applicable qualification test levels. In addition, derived from the "CubeSpace generation 2 Environmental Qualification plan", a detailed Environmental Test Procedure and Results document was created for the CubeSense Earth. The CubeSense Earth Environmental Test Procedure and Results document further detailed the exact procedure steps to be taken during a particular environmental test as well as the expected results that must be achieved to claim a qualification level "PASS" against a test.

The detailed test sequences are outside the scope of this document. Only the applicable qualification test levels are indicated in the sub-sections below.

6.2 Thermal (Cold Start and Hot start) qualification testing.

The CubeSense Earth, while not powered, is subjected to a cold start temperature of -35 degC. Once the soak period of a minimum of 30 minutes has passed, the CubeSense Earth is powered up and its start-up sequence is monitored for correct operation and if successful, a brief health check is done. The CubeSense Earth is then powered down and the temperature is raised to +70 degC and the power-up sequence and brief heath check is repeated. The CubeSense Earth is again powered down and brought back to ambient temperature. A complete ATP is then conducted and if all tests pass, the CubeSense Earth is deemed to have passed its Thermal (Hot and Cold start) qualification test.

6.3 Thermal / Vacuum (TVAC) qualification testing

The components used in all CubeProducts are non-outgassing and are specifically chosen to fall within the CVCM < 0.1%, TML < 1% limits.

For every TVAC cycle (for both hot and cold extremes – see tables below) the CubeSense Earth is subjected to a full health check test procedure. Once all cycles have been completed, the CubeSense Earth is subjected to a full Acceptance Test Procedure. If the CubeSense Earth passes all tests, it is deemed to have passed TVAC testing at qualification levels.

Table 14: TVAC Hot cycle qualification levels

TVAC PARAMETER	TEST LEVEL
Chamber Pressure	1e-3 Pa or 1e-5 mBar

TVAC PARAMETER	TEST LEVEL
Number of Cycles	4
Dwell time after thermal stabilisation	1h
Temperature Tolerance	±2 °C
Temperature ramp rate	1 °C/min
Maximum Temperature (Qualification)	+80±2°C

Table 15: TVAC Cold cycle qualification levels

TVAC PARAMETER	TEST LEVEL
Chamber Pressure	1e-3 Pa or 1e-5 mBar
Number of Cycles	4
Dwell time after thermal stabilisation	1h
Temperature Tolerance	±2 °C
Temperature ramp rate	1 °C/min
Minimum Temperature (qualification)	-20±2°C

6.4 Vibration qualification testing

For each of the three axes of the CubeSense Earth, once a particular vibration type of test is done (see tables below), it is physically inspected for any damage and then subjected to a full health check test procedure. Once all vibration type tests have been completed the CubeSense Earth is subjected to a full Acceptance Test Procedure. If the CubeSense Earth passes all tests, it is deemed to have passed Vibration testing at qualification levels.

Table 16: Low-level sine resonance search levels

FREQUENCY (HZ)	AMPLITUDE (G) [0-PK]
5	1
2000	1
Sweep rate	2 Oct/min

The **success criteria** for the resonance search are:

- Less than 5% change in the average frequency of peaks displayed by the accelerometer placed on the DUT.
- Less than 20% in amplitude shift

Table 17: Qualification sine plus quasi-static levels

FREQUENCY (HZ)	AMPLITUDE (G) [0-PK]
5	1
10	2.5
21	2.5
25	15

FREQUENCY (HZ)	AMPLITUDE (G) [O-PK]
30	15
35	3
110	3
125	0.25
Sweep rate	2 Oct/min

Table 18: -3dB random vibration qualification levels

FREQUENCY (HZ)	AMPLITUDE (G^2/HZ)
20	0.0282
50	0.0802
800	0.0802
2000	0.0130
Duration	60 seconds
Grms	10.02

Table 19: Random vibration qualification levels

FREQUENCY (HZ)	AMPLITUDE (G^2/HZ)
20	0.0563
50	0.1600
800	0.1600
2000	0.0260
Duration	120 seconds
Grms	14.16

6.5 Shock qualification testing

For each of the three axes of the CubeSense Earth, once a particular shock test is done (see table below), it is physically inspected for any damage and then subjected to a full health check test procedure. Once tests in all axes have been completed the CubeSense Earth is subjected to a full Acceptance Test Procedure. If the CubeSense Earth passes all tests, it is deemed to have passed Shock testing at qualification levels.

Table 20: Qualification shock test levels

FREQUENCY [HZ]	SHOCK SPECTRUM VALUES [G] - 3DB (LOWER-LEVEL THRESHOLD)	SHOCK SPECTRUM VALUES [G] (NOMINAL QUALIFICATION LEVELS)	SHOCK SPECTRUM VALUES [G] +6DB (UPPER-LEVEL THRESHOLD)
30	2	5	20
1000	750	1500	6000
10000	750	1500	6000

6.6 Radiation

For the CubeSpace generation 2 product line, the minimum successful TID level is defined as 24 kRad at a 95% confidence level. (This is calculated for 3 units tested as: Rating = Mean – 3*STD)

6.7 EMI / EMC

As mentioned in this chapter's introduction only EMI / EMC characterisation sessions have taken place to date. No formal EMI / EMC testing has been done to date.

7 Materials used.

A Declared Materials List document is available for the CubeSense Earth and is optionally available from CubeSpace and should be specifically requested during order placement.