CUBESPACE

CubeStar Generation 2

Interface Control Document (ICD)

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Revision History

VERSION	AUTHORS	DATE	DESCRIPTION
A	C. Leibbrandt	15/06/2023	First draft release
B	C. Leibbrandt	28/08/2023	Update after initial review
1.00	C. Leibbrandt	28/08/2023	First Published version

Reference Documents

The following documents are referenced in this document.

[1] CS-DEV.PD.CT-01 CubeStar Product Description Ver.1.00 or later

[2] CS-DEV.UM.CT-01 CubeStar 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 CubeStar as described in [1]. The purpose of this document is to provide Interface Control Document (ICD) related information about the CubeStar.

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

Table 1: Document Applicability

CUBEPRODUCT	VERSION	NOTES
CubeStar	M2.0E5.3	With or without the standard 120° baffle mounted.

2 Electrical Interface

This chapter describes the electrical interfaces of the CubeStar. This includes:

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

2.1 CubeStar Communication interface(s)

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

- CAN
- UART
- RS485 (custom option)

2.1.1 CAN Characteristics

The characteristics for the CubeStar CAN bus are given in Table 2.

Table 2: CAN bus characteristics for CubeStar

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 CubeStar UART interface are given in Table 3.

Table 3: UART characteristics for CubeStar

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

2.1.3 RS485 characteristics (custom option)

RS485 communication with the CubeStar 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 interface is the same as in Table 3. Additional RS485 characteristics are given in Table 4

Table 4: RS485 characteristics for CubeStar

PARAMETER	VALUE
Data Enable (DE) polarity	High

2.1.4 CubeStar Enable line.

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

2.2 CubeStar Power supply

Table 5 below summarizes the power supply voltages to be supplied by the client ADCS / OBC.

Table 5: CubeStar external power supply requirements

EXTERNAL POWER	
Supply voltage [V]	3.3
Peak power [mW]	271
Average power [mW]	165

2.2.1 Power consumption: 3.3V rail

The CubeStar has an average power consumption on the 3.3 V line independent of the satellite's size or ADCS modes used. This is as 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 CubeStar are shown in Table 6.

Table 6: CubeStar Average power consumption and inrush current on 3.3 V line (no actuation)

SUBSYSTEM	3.3 V RAIL					NOTES
	Avg Current (mA)	Avg Power (mW)	Max Current (mA)	Max Power (mW)	Inrush (mA – µs)	
CubeStar	50	165	83	274	180-1800	Measured during 1 Hz detection.

2.2.2 Power Protection

CubeStar Power Protection is included. Specifically, if the 3V3 power supplied externally falls outside the 2.5V – 3.9V range, the CubeStar will automatically switch off.

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

2.2.2.1 CubeStar 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 CubeStar. This will ensure protection of the CubeStar from undervoltage conditions and helps protect memory and other sensitive circuits on the CubeStar.

It is suggested that the client ADCS / OBC should provide current limiting for the 3V3 power supply to the CubeStar 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 CubeStar is connected to the client ADCS / OBC, similar protection is suggested.

2.2.2.2 CubeStar 3V3 power switch

The CubeStar implements an input power switch. It is enabled by pulling the Enable line high for the CubeStar. This switch allows the client ADCS / OBC to isolate it from the 3V3 power rail. The CubeStar 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

A standalone CubeStar will ship with two harnesses, an EM harness as part of the ground support equipment package to allow for immediate testing and health checks and an FM pigtail harness that can be used by the client to assemble a flight harness. The default length of the pigtail harness is 400mm (which can be cut shorter), custom (longer) lengths can be arranged by indicating so when the order is placed.

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

The CubeStar standard FM pigtail harness characteristics are described in Table 7 below. In Table 7, the housing and terminal details refer to the housing that mates with the CubeStar itself, i.e. are supplied on the one side of the pigtail harness.

Table 7: CubeStar Harness characteristics

HARNESS	HOUSING MASS (mg)	TERMINAL MASS (mg)	WIRE GAUGE (AWG)	WIRE MASS (kg/km)	PINS	TOTAL[1] MASS (g)
CubeStar Sensor	198.8	35.434	26	1.96	10	8.4

2.3.1 Harness Header on CubeStar

A 10 pin Molex 5055671081 right angle header provides the electrical interface to CubeStar. The details are described in Table 8.

Table 8: CubeStar Electrical Interface

CUBESTAR INTERFACE DETAILS				
Header Type:	Molex Micro-lock Plus, single row 5055671081			
Number of pins	10			
Mating Housing	Molex Micro-Lock Plus Receptacle Crimp Housing 5055651001			
Housing Terminal	Molex Micro-Lock Female crimp Terminal, Gold, 26-30 AWG, 5054311100			
CUBESTAR 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 electronics.	Power	0
3	3V3	Supply voltage for the digital electronics.	Power	3.2 to 3.4

[1] This is the weight of the supplied pigtail harness and therefore excludes the chosen ADCS / OBC mating parts.

CUBESTAR INTERFACE DETAILS				
4	UART Tx /RS485 Tx	UART/RS485 Data Transmit of MCU.	Output	-0.5 to 3.4
5	CAN P	High level CAN bus line.	LVDS	-3.4 to 3.4
6	CAN N	Low level CAN bus line.	LVDS	-3.4 to 3.4
7	UART Rx /RS485 Rx	UART/RS485 Data Receive of MCU.	Input	-0.5 to 3.4
8	GND	Power ground of electronics.	Power	0
9	GND	Power ground of electronics.	Power	0
10	Enable	Active high enable.	Input	-0.3 to 3.4 V_{low} < 0.95 V_{high} > 1.05

3 Mechanical Interface

This chapter describes the mechanical interface of the CubeStar. This includes:

1. The outer dimensions of the CubeStar,
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 CubeStar

The CubeStar star tracker is fully enclosed in an aluminium housing manufactured from AL 6082-T6, treated with a chromate conversion coating (Alodine), that rigidly supports the lens. The enclosure has a section of M24x1.5mm thread for the addition of a baffle to improve the performance of CubeStar[2]. A Molex Micro-lock connector is used to interface with the CubeStar as shown in Figure 1.

3.1.1 Outer Dimensions

Figure 1 shows the indicative outer dimensions of CubeStar (without baffle).

[2] In this document, only the standard 120° baffle is discussed. If a custom baffle is required, the relevant values that will differ from what is given in this document can be requested from CubeSpace.

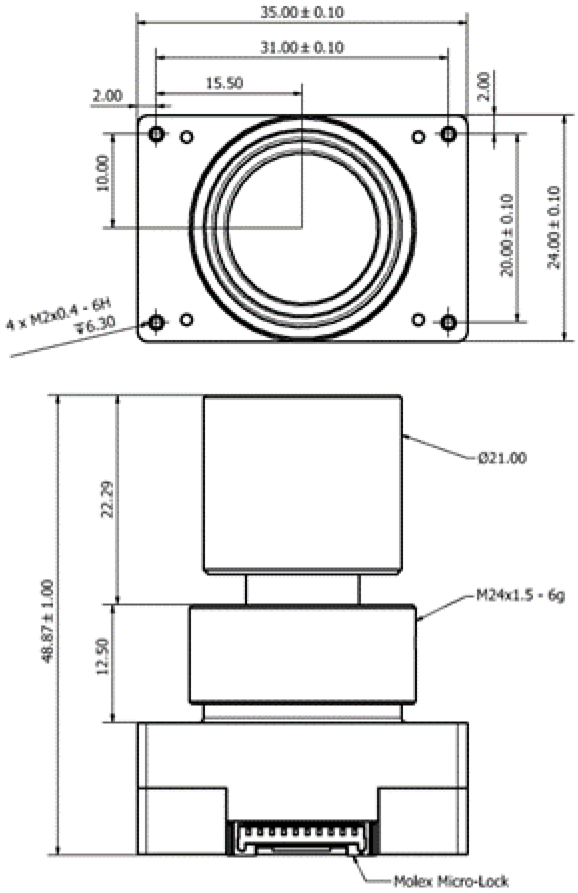

Figure 1: Indicative dimensions of CubeStar (without baffle)

Figure 2 shows the indicative outer dimensions of CubeStar with a baffle.

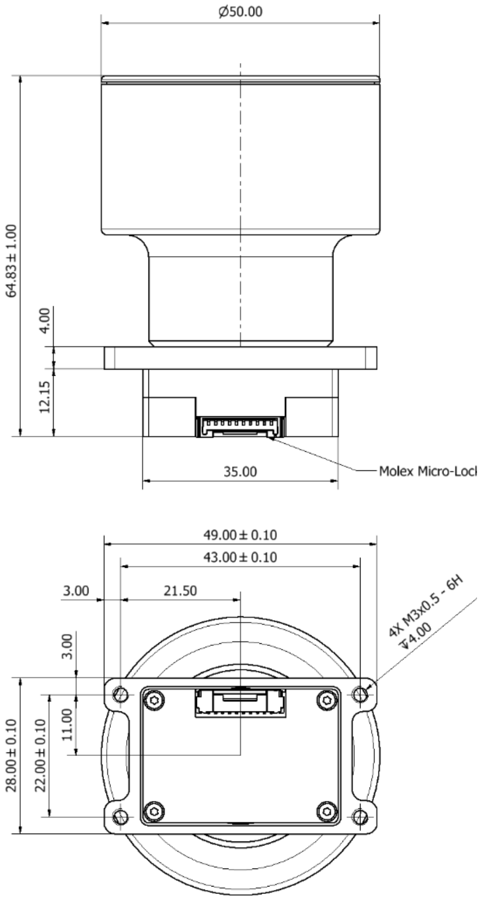

Figure 2: Indicative dimensions of CubeStar with baffle assembly

3.1.2 Mounting definition

Mounting of the CubeStar is performed through four (4) blind M2x0.4mm threaded holes as shown in Figure 1. The CubeStar can only be secured/mounted via the threaded holes on the face (lens side) of the enclosure as indicated. The lens of the CubeStar does not require additional external support, it is sufficiently supported by the housing.

If the standard baffle is selected for inclusion with a CubeStar to improve the performance, an additional mounting bracket (included in the baffle assembly) is required to allow for mounting of the CubeStar and baffle. Such an assembly is shown in Figure 2. The adaptor bracket has four (4) M3x0.5mm threaded holes, as shown in Figure 2, to be used for mounting of the CubeStar and baffle assembly (note that the mounting holes as indicated in Figure 1 is not to be used as a result).

3.1.3 Mass, COM and Inertia

Table 9 details the mass of the CubeStar.

Table 9: CubeStar mass

CUBESTAR	VARIANT/MODEL	MASS (G)	NOTES
CubeStar	NA	47[3]	Measured
CubeStar and baffle assembly	NA	97.6[4]	Calculated from CAD Model

Figure 3 displays the COM position of the CubeStar without a baffle, and Figure 4 shows the COM position of the CubeStar and baffle assembly.

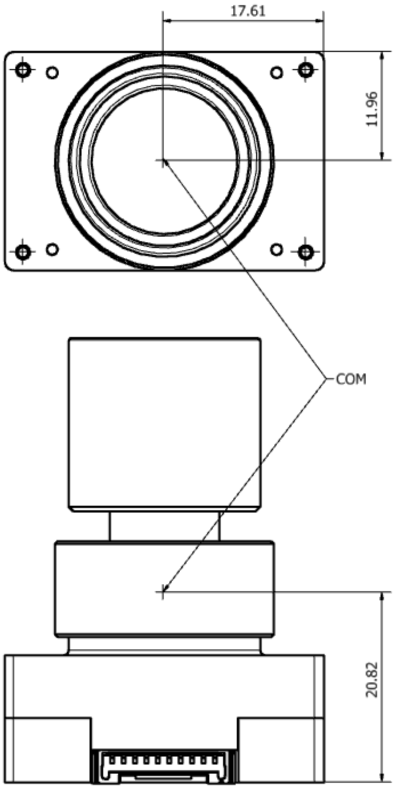

Figure 3: COM position of CubeStar (without baffle)

[3] 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).

[4] This weight will be additional to the CubeStar itself.

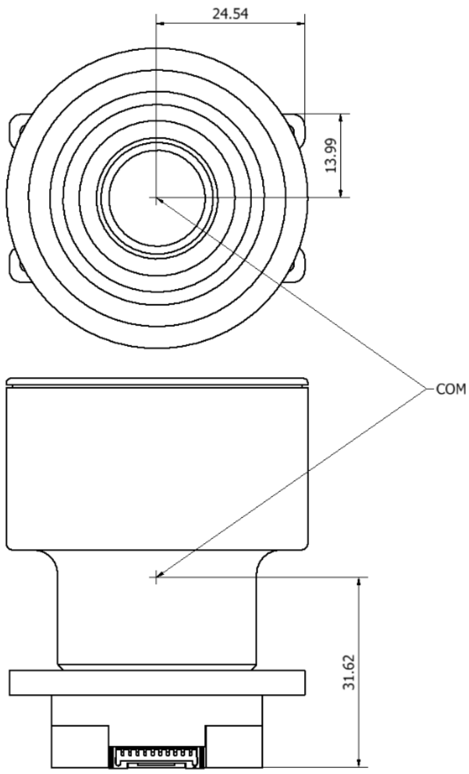

Figure 4: COM position of CubeStar and baffle assembly

The moments of inertia of the CubeStar about the COM position are presented in Table 10, while the axes reference for the inertias provided is shown in Figure 5.

Table 10: CubeStar Moments of Inertia (MOI)

AXIS	VALUE (gmm^2)
I_{xx} (without baffle)	6710 ± 10 %
I_{yy} (without baffle)	6548 ± 10 %
I_{zz} (without baffle)	530 ± 10 %
I_{xx} (with baffle)	44556 ± 10 %
I_{yy} (with baffle)	45386 ± 10 %
I_{zz} (with baffle)	27350 ± 10 %

3.1.4 Measurement Coordinate System Definition

The coordinates system definition used by the CubeStar is presented in Figure 5

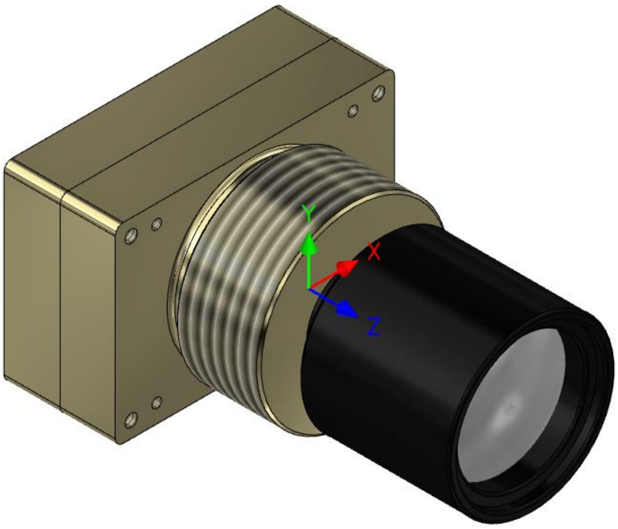

Figure 5: CubeStar Coordinate system definition.

4 EMI / EMC

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

4.1 Potential RF emitter list

Table 11: CubeStar Potential Emitters

COMPONENT	EMITTER TYPE	FREQUENCY	FREQ. STABILITY
Image Sensor Crystal	Crystal	20 MHz	± 50 ppm
Comms UART	UART	921.6 kHz	± 50 ppm
Comms CAN	SPI	1 MHz	± 50 ppm
SRAM	FMC	3 MHz	± 50 ppm
NAND Flash	QSPI	4.8 MHz	± 50 ppm
MCU	Crystal	24 MHz	± 50 ppm

4.2 Minimising EMI / EMC effects

4.2.1 Grounding

The enclosure and mechanical parts of CubeStar are connected to the electrical ground through a filter designed to minimise EMI, as illustrated by Figure 6, with “ADCS node 1” representing the CubeStar. (Note that a generic CubeADCS diagram is shown to explain the grounding strategy followed, for consideration by the client). The enclosure of the CubeStar can be grounded by the user if desired.

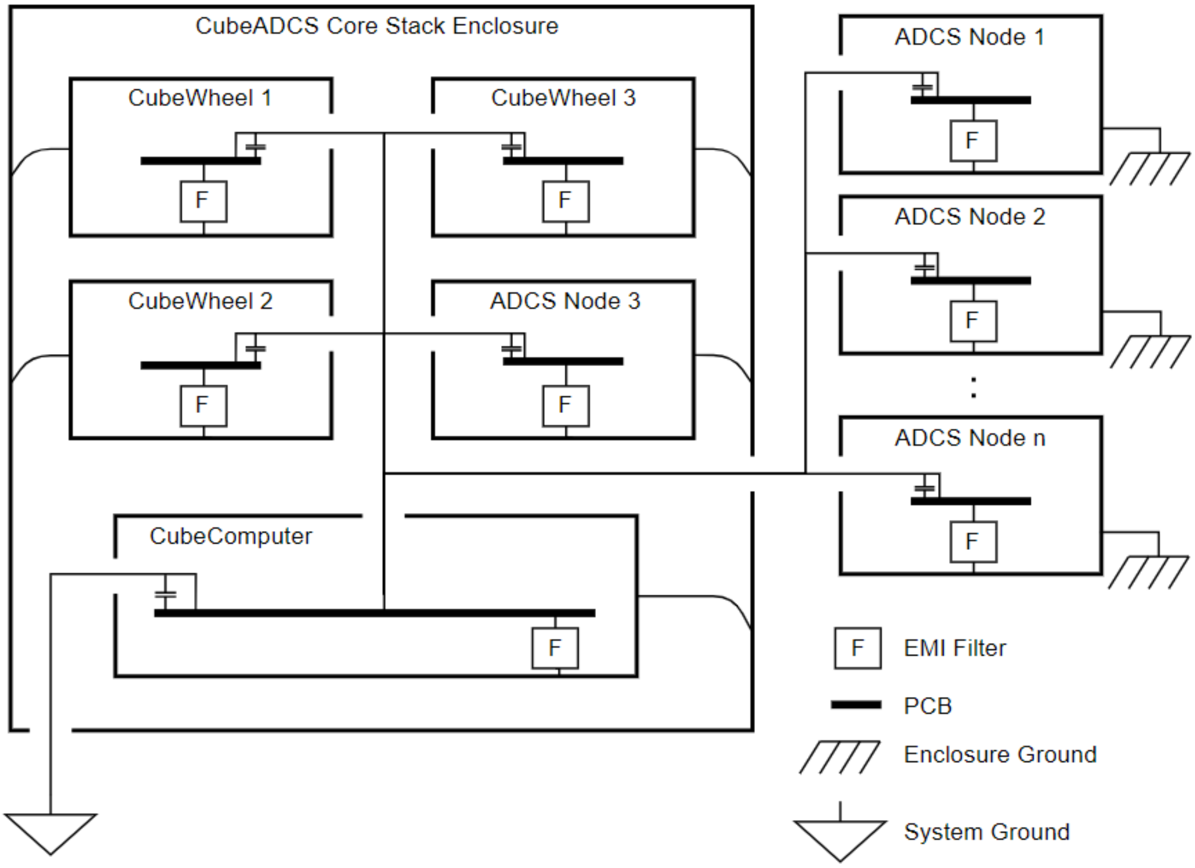

Figure 6: Generic Grounding diagram

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 CubeStar 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.

4.2.2 Shielding

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

4.2.3 Filtering and Suppression

The following noise filtering schemes are utilised on the CubeStar:

a. All pins that are externally exposed through headers are filtered by way of 100pF decoupling to ground as shown in Figure 6.
b. LC filtering is done on the CubeComputer's external 5V and 3.3V power supply input lines.
    - For the standalone CubeStar, 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 CubeStar, 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 CubeStar, 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 and UART 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 CubeStar, the client is requested to consider implementing similar on the client ADCS / OBC side – details can be provided.

5 Environmental Qualification

CubeSpace has recently completed a so-called “re-spin” of all generation 2 CubeProducts, including the CubeStar. 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 of the production line. A completion date of end 2023 is targeted. This chapter will then be updated accordingly documenting the formal qualification status of the CubeStar.

5.1 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 CubeStar, together with the applicable qualification test levels. In addition, derived from “CubeSpace generation 2 Environmental Qualification plan”, a detailed Environmental Test Procedure and Results document was created for the CubeStar. The CubeStar 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 sub-sections below.

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

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

5.3 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 CubeStar is subjected to a full health check test procedure. Once all cycles have been completed, the CubeStar is subjected to a full Acceptance Test Procedure. If the CubeStar passes all tests, it is deemed to have passed TVAC testing at qualification levels.

Table 12: 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 13: 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

5.4 Vibration qualification testing

For each of the three axes of the CubeStar, 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 CubeStar is subjected to a full Acceptance Test Procedure. If the CubeStar passes all tests, it is deemed to have passed Vibration testing at qualification levels.

Table 14: 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 15: Qualification sine plus quasi-static levels

FREQUENCY (HZ)	AMPLITUDE (G) [0-PK]
5	1
10	2.5
21	2.5
25	15
30	15

FREQUENCY (HZ)	AMPLITUDE (G) [0-PK]
35	3
110	3
125	0.25
Sweep rate	2 Oct/min

Table 16: -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 17: 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

5.5 Shock qualification testing

For each of the three axes of the CubeStar, 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 CubeStar is subjected to a full Acceptance Test Procedure. If the CubeStar passes all tests, it is deemed to have passed Shock testing at qualification levels.

Table 18: 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

5.6 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)

5.7 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.

6 Materials used.

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