CUBESPACE

CubeWheel Generation 2

Interface Control Document (ICD)

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Revision History

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B	C. Leibbrandt	14/06/2023	Version update after initial review
1.00	C. Leibbrandt	14/06/2023	Published
1.01	J. Miller	14/07/2023	Update to Table 15
1.02	J. Miller	10/10/2023	Update torque graphs and tables.

Reference Documents

The following documents are referenced in this document.

[1] CS-DEV.PD.CW-01 CubeWheel Product Description Ver.1.00 or later

[2] CS-DEV.UM.CW-01 CubeWheel 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
ESL	Equivalent Series inductance (L)
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
TVAC	Thermal Vacuum Chamber
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 CubeWheel as described in [1]. The purpose of this document is to provide Interface Control Document (ICD) related information about the CubeWheel.

A CubeWheel User Manual is also available, typically provided post order placement (see [2]).

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

Table 1: Document Applicability

CubeProduct	Version	Notes
CubeWheel	M2.0E2.3	All sizes

2 Electrical Interface

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

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

2.1 CubeWheel Communication interface(s)

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

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

2.1.1 CAN Characteristics

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

Table 2: CAN bus characteristics for CubeWheel.

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 CubeWheel UART interface are given in Table 3.

Table 3: UART characteristics for CubeWheel

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 CubeWheel 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 are the same as in Table 3. Additional RS485 characteristics are given in Table 4

Table 4: RS485 characteristics for CubeWheel

PARAMETER	VALUE
Data Enable (DE) polarity	High

2.1.4 I2C Characteristics (custom option)

I2C communication with the CubeWheel is provided as a custom option and must specifically be specified by the client at the time of order placement. The CubeWheel 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 CubeWheel must support clock stretching. The relevant I2C characteristics for the CubeWheel are given in Table 5.

Table 5: I2C bus characteristics for CubeWheel

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 CubeWheel Power supply

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

Table 6: CubeWheel external power supply requirements

EXTERNAL POWER	CW0017	CW0057	CW0162	CW0500*	CW1200*	CW2500*	CW5000*
Digital Supply Voltage [V]	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Motor Supply Voltage Range [V] (Vbat)	6.4-16.8	6.4-16.8	6.4-16.8	TBD	TBD	TBD	TBD
Nominal Motor Supply Voltage	8	12	12	12	16	TBD	TBD

* - In development.

2.2.1 Power consumption: 3.3V rail

The CubeWheel 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 CubeWheel are shown in Table 7.

Table 7: CubeWheel 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)	
CubeWheel (Variants CW0017, CW0057, CW0162)	32	105.6	79	260.7	270-0.5	Measured for all modes
CubeWheel (Variants CW500, CW1200, CW2500, CW5000)*	TBC	TBC	TBC	TBC	TBC	Still in development

* - In development

2.2.2 Power consumption: Battery Voltage Rail

The CubeWheels (as Reaction wheels) are responsible for maintaining the satellite's desired attitude by counteracting the in-orbit disturbance torques and by rotating the satellite to achieve the required manoeuvre. The power consumption of reaction wheels are dependent on both the running speed as well as the torque demand.

The current draws at different momentum levels are shown in Figure 3 to Figure 6. The negative side of the graphs indicate the current draw during braking. When the wheel speed crosses the zero value, there is a significant current spike to keep the tracking error as low as possible.

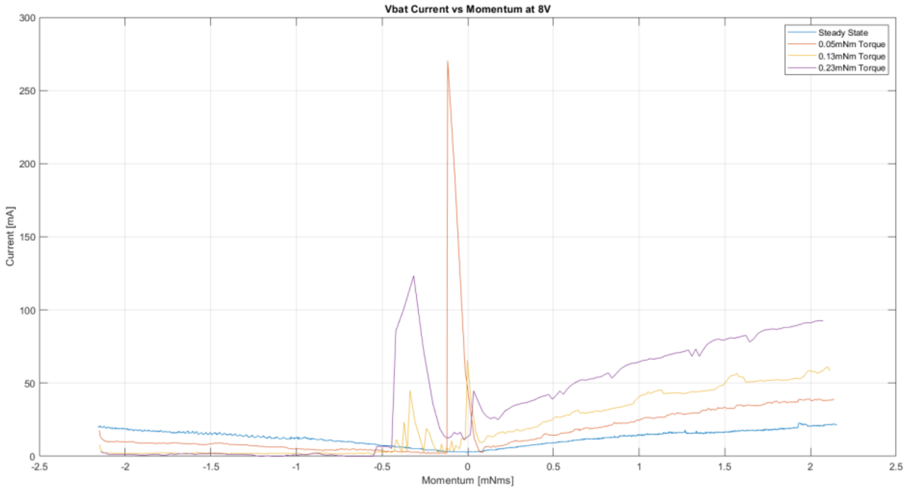

Figure 1: CubeWheel 0017 current draw at 8V supply

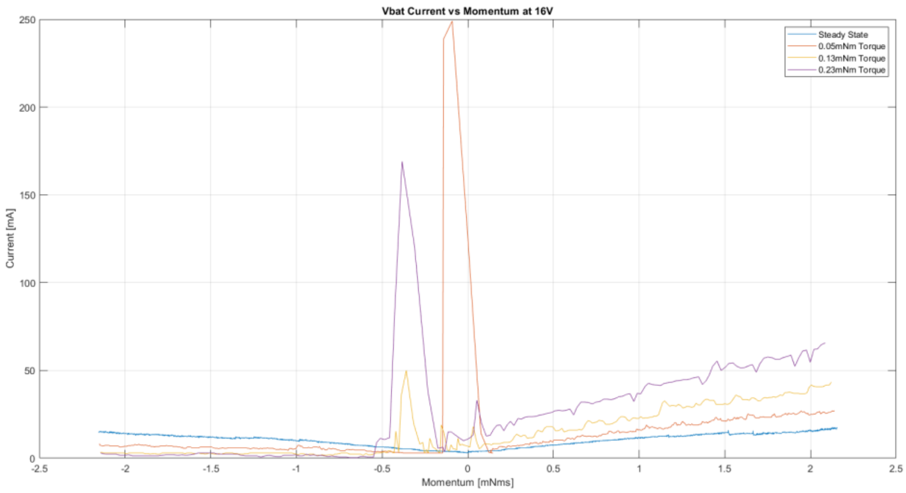

Figure 2: CubeWheel 0017 current draw at 16V supply

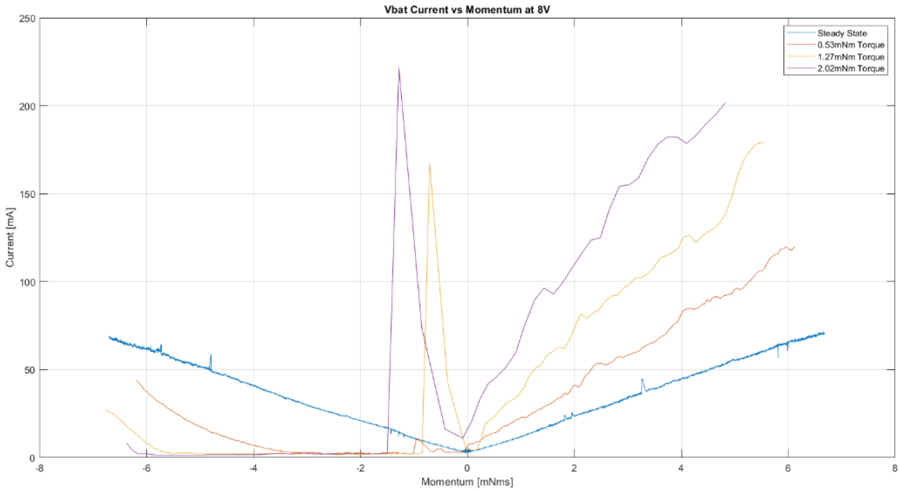

Figure 3: CubeWheel 0057 current draw at 8V supply

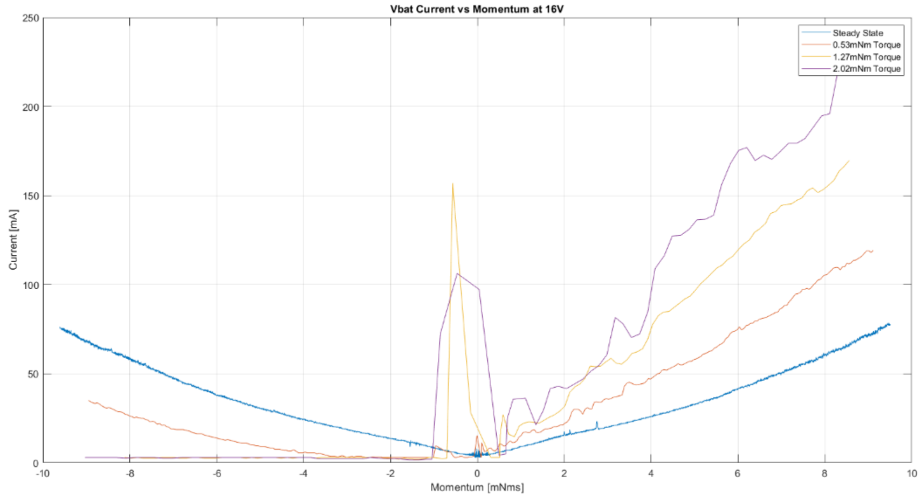

Figure 4: CubeWheel 0057 current draw at 16V supply

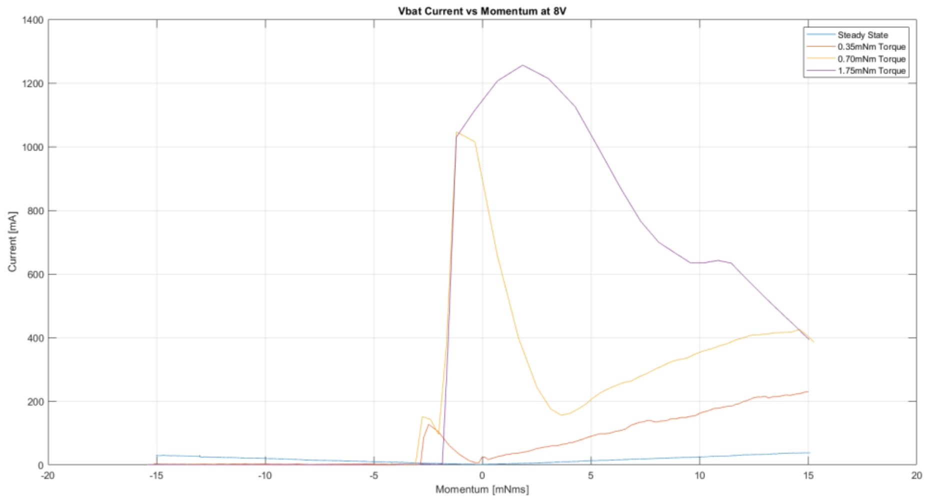

Figure 5: CubeWheel 0162 current draw at 8V supply

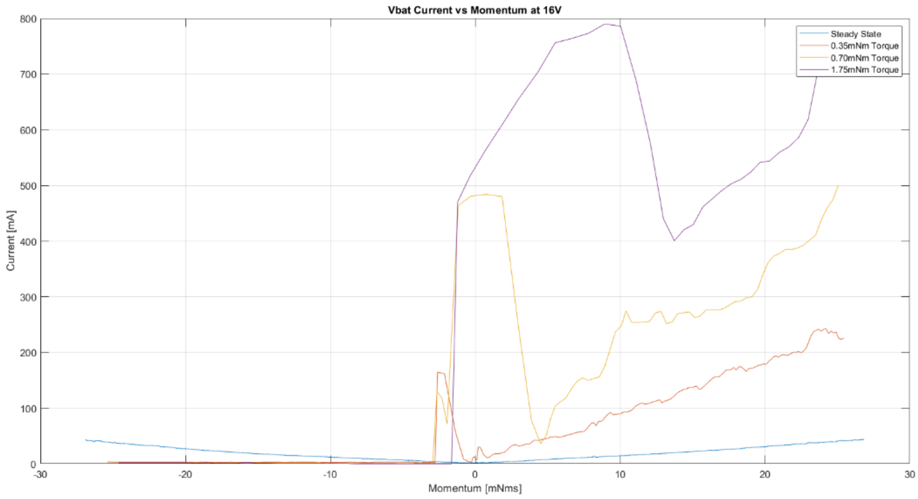

Figure 6: CubeWheel 0162 current draw at 16V supply

Maximum current at the various supply voltages is given in Table 8 for the CubeWheel variants. The maximum current is drawn in short pulses at 24 kHz which is equal to the frequency of the PWM used in the motor driver.

Table 8: Maximum current draw from battery supply

CUBEWHEEL VARIANT	MAX CURRENT AT 8V [MA]	MAX CURRENT AT 10V [MA]	MAX CURRENT AT 12V [MA]	MAX CURRENT AT 14V [MA]	MAX CURRENT AT 16V [MA]
CW0017	330	405	370	300	280
CW0057	624	648	656	672	704
CW0162	776	880	952	1010	1030
CW500*	TBD	TBD	TBD	TBD	TBD
CW1200*	TBD	TBD	TBD	TBD	TBD
CW2500*	TBD	TBD	TBD	TBD	TBD
CW5000*	TBD	TBD	TBD	TBD	TBD

* - In development

2.2.3 Power Protection

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

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

There is protection against overvoltage on the $V_{Battery}$ bus line, if the $V_{Battery}$ power supplied falls outside the 6.2V-20V range, the power to the motor driver will automatically switch off. A voltage input above 20V will cause damage.

2.2.3.1 CubeWheel Enable line.

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

2.2.3.2 CubeWheel 3V3 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 Enable line to the CubeWheel. This will ensure protection of the CubeWheel from undervoltage conditions and helps protect memory and other sensitive circuits on the CubeWheel.

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

2.2.3.3 CubeWheel 3V3 power switch

The CubeWheel implements an input power switch. It is enabled by pulling the Enable line high for the CubeWheel. This switch allows the client ADCS / OBC to power off the CubeWheel and isolate it from the 3V3 power rail. The CubeWheel 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 CubeWheel is designed to connect to the CubeADCS via a dedicated harness with Molex Micro-Lock plus housings crimped on to 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 CubeWheel is placed.

A standalone CubeWheel 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 CubeWheel standard FM pigtail harness characteristics are described in Table 9 below. In Table 9, the housing and terminal details refer to the housing that mates with the CubeWheel itself, i.e. are supplied on the one side of the pigtail harness.

Table 9: CubeWheel Harness Characteristics

	Wire Gauge (AWG)	Wire mass (kg/km)	Housing mass (mg)	Terminal mass (mg)	pins	Total[1] Mass
CubeWheel Actuator	26	1.96	263.5	35.434	14	

2.3.1 Harness header on CubeWheel

A 14 pin Molex **5055671481** right angle header provides the electrical interface to CubeWheel. The details are described in Table 10.

Table 10: CubeWheel interface details

CUBEWHEEL INTERFACE DETAILS	
Header Type:	Molex 5055671481
Number of pins	14
Mating Housing	Molex 5055651401
Housing Terminal	5037650098

CUBEWHEEL HEADER PIN DEFINITIONS				
Pin #	Pin Name	Pin Description	IO Type	Voltage range [V]
1	BOOT	Pull this pin high to enter ROM bootloader.	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 Tx	UART/RS485 Data Transmit of CubeWheel MCU. Pull high if unused.	Output	-0.5 to 3.4
5	CAN_H	High level CAN bus line	Differential	-3.4 to 3.4
6	CAN_L	Low level CAN bus line	Differential	-3.4 to 3.4
7	UART_RX /RS485 Rx	UART/RS485 Data Receive of CubeWheel MCU. Pull high if unused.	Input	-0.5 to 3.4
8	GND	Power ground of CubeWheel electronics	Power	0
9	GND	Power ground of CubeWheel electronics	Power	0
10	Enable	Pull this pin high to enable CubeWheel	Input	-0.5 to 3.4 $V_{low} < 0.95$ $V_{high} > 1.05$
11	GND	Power ground of CubeWheel electronics	Power	0
12	GND	Power ground of CubeWheel electronics	Power	0
13	VBAT	Supply voltage for motor driver	Power	6.4 to 16.8 [1]

[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.

CUBEWHEEL INTERFACE DETAILS				
14	VBAT	Supply voltage for motor driver	Power	6.4 to 16.8 [1]

[1] The voltage applied to the motor determines what the maximum steady state speed will be.

2.3.2 CubeWheel Pyramid Electrical Interface

The CubeWheel pyramid interface has four individual/separate interfaces, each the same as defined in section 2.3.1.

3 Mechanical Interface

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

1. The outer dimensions of the CubeWheel,
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 CubeWheel

The CubeWheel reaction wheel comprises a high-performance electric motor driving a balanced flywheel. These components are housed within a robust enclosure made from 6082-T6 aluminium treated with a chromate conversion coating (Alodine).

3.1.1 Outer Dimensions

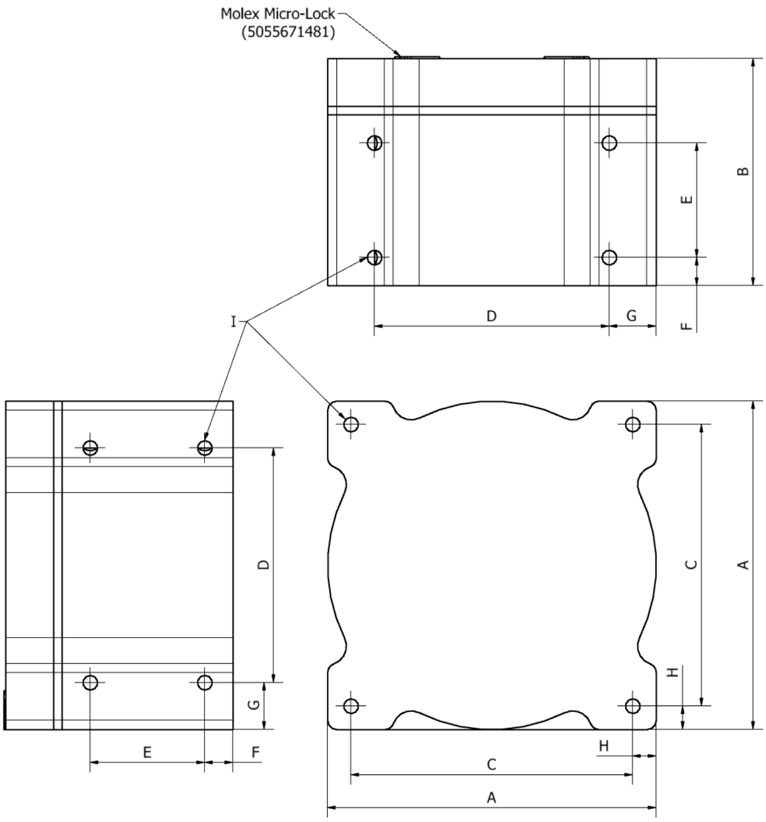

Figure 7: Indicative dimensions of CubeWheel

Table 11: CubeWheel dimensions for each variant

MODEL	MOMENTUM @ 6000 RPM (MNMS)	A (MM)	B (MM)	C (MM)	D (MM)	E (MM)	F (MM)	G (MM)	H (MM)	I
CW0017	1.7	28.0±0.1	26.0±0.1	23.0±0.1	23.0±0.1	10±0.1	5.0	2.5	2.5	M2x0.4 4.00 Deep
CW0057	5.7	35.0±0.1	24.2±0.2	30.0±0.1	25.0±0.1	12.2±0.1	3.0	3.0	3.0	M2x0.4 4.00 Deep
CW0162	16.2	46.2±0.1	24.2±0.2	39.8±0.1	32.2±0.1	13.2±0.1	2.5	2.5	2.5	M3x0.5 4.5 Deep (Helicoil)
CW500*	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
CW1200*	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
CW2000*	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
CW5000*	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

* - In development

3.1.2 Mounting definition

Mounting of wheels should be to a rigid part of the satellite and ideally to more than one side of the wheel. Improper mounting or a flimsy structure can easily result in vibration amplification that can damage the wheel bearings. Fasten the wheels using a torque wrench to achieve 1.2 Nm for the M3 helicoil protected holes and between 0.25 and 0.30 Nm for the M2 threaded aluminium holes. Ensure that all mounting screws are secured using non-outgassing epoxy before conducting vibration tests.

Each CubeWheel has three orthogonal faces with four mounting holes on each face. Refer to Figure 7 for the dimensions of these mounting holes.

3.1.3 Mass, COM and Inertia

The mass, COM and Inertia of each respective CubeWheel variant are shown in Table 12. This table also gives the flywheel inertia. The flywheel is free to spin when the motor is not actively controlling the rotation and should therefore not contribute to the total satellite inertia.

The position of the COM and its respective dimensions K, L and M are shown in Figure 8. The reference frame for all dimensions provided in Table 12 is displayed in Figure 9.

Table 12: CubeWheel mass, COM and inertia for each variant

MODEL	MASS (G)	COM (MM)			INERTIA AROUND COM (GMM²)			FLYWHEEL INERTIA (GMM²)
		K	L	M	I_{xx}	I_{yy}	I_{zz}	
CW0017	55	14.25	13.6	12.62	6034	5798	6786	2058

MODEL	MASS (G)	COM (MM)			INERTIA AROUND COM (GMM²)			FLYWHEEL INERTIA (GMM²)
CW0057	101	17.37	17.51	9.86	12944 ± 10%	12846 ± 10%	18306 ± 10%	9182
CW0162	144	20.35	23.10	10.92	31926 ± 10%	31817 ± 10%	51640 ± 10%	25666
CW500*	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
CW1200*	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
CW2000*	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
CW5000*	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

* - In development

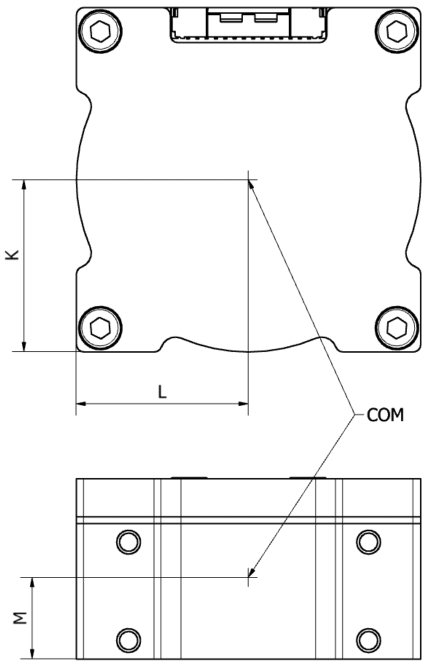

Figure 8: COM position of CubeWheels

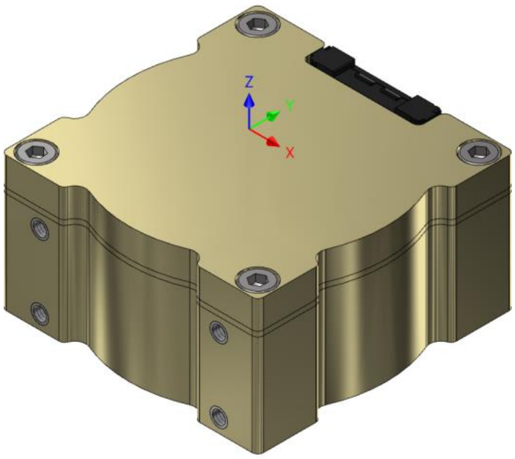

Figure 9: CubeWheel local component reference frame

3.1.4 Coordinate System Definition

A positive rotation (resulting from a positive wheel speed reference command or duty cycle command) can be translated to an angular momentum vector pointing out of the top of CubeWheel as shown in Figure 10.

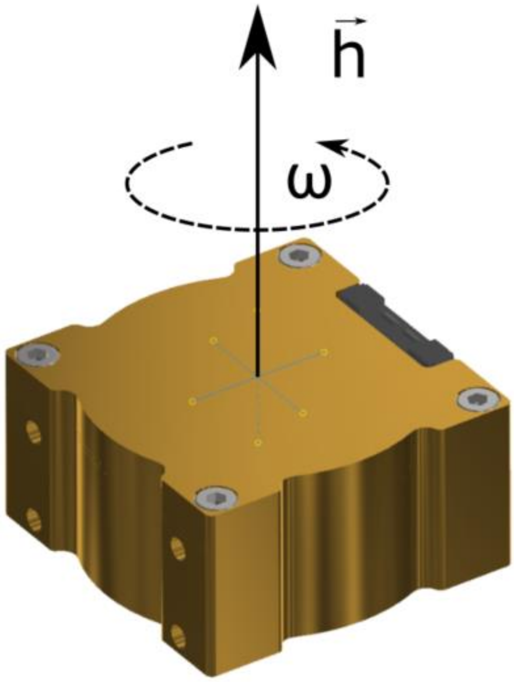

Figure 10: Momentum definition of a CubeWheel

3.1.5 CubeWheel Magnetic Dipole

The CubeWheels size variants have static magnetic dipoles shown in Table 13.

Table 13: CubeWheel magnetic dipole

MODEL	MAGNETIC DIPOLE [mAM^2]
CW0017	0.9
CW0057	1.8
CW0162	2.5

MODEL	MAGNETIC DIPOLE [mAM^2]
CW500*	TBD
CW1200*	TBD
CW2000*	TBD
CW5000*	TBD

* - In development

These dipoles may cause disturbances on sensitive sensor payloads and therefore should be placed as far as possible from such sensors.

3.1.6 Power characteristics

To achieve the maximum rotation speed (thus momentum), the CW0057 and CW0162 wheel variants requires a battery supply voltage of at least 11V, the CW0017 will achieve maximum rotation speed at a battery supply of at least 6.4V. The wheel will still operate with lower supply voltages but will have correspondingly lower momentum storage. The voltage range for the supply must be between 6.4V and 16.8V.

A similar restriction is valid for the current vs torque relationship. A wheel requires a minimum of 1.5 A to achieve the 10 mNm specification. Less powerful supplies will have correspondingly lower torque capability from the wheels.

3.2 CubeWheel Pyramid

The CubeWheel pyramid consists of four reaction wheels mounted in a pyramid configuration. Each reaction wheel in the pyramid configuration is inclined at an angle of 26.57 degrees.

3.2.1 Outer Dimensions

The physical size for each CubeWheel Pyramid configuration is provided in Table 14 in reference to Figure 11.

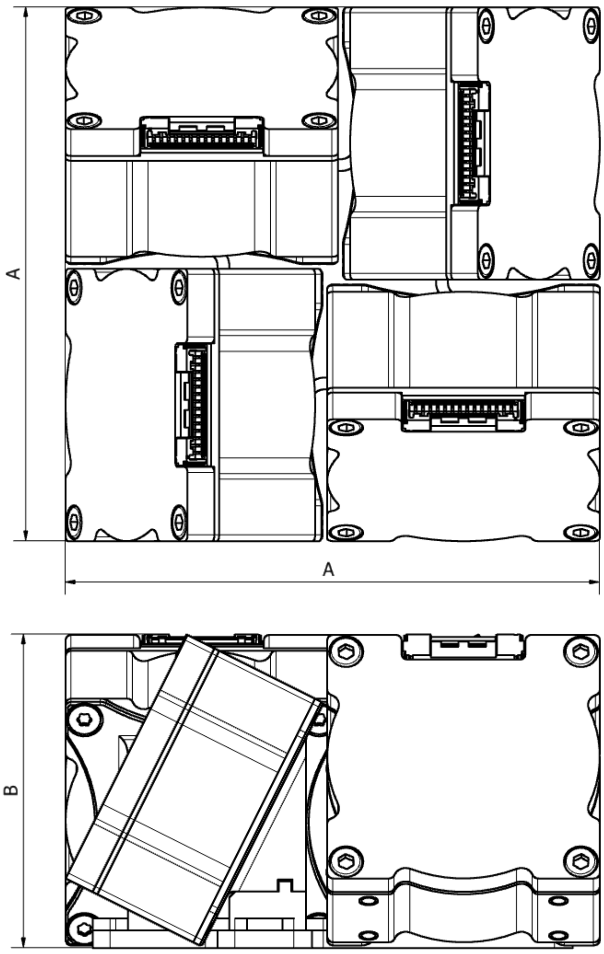

Figure 11: Indicative dimensions of a CubeWheel Pyramid of reaction wheels

Table 14: CubeWheel Pyramid dimensions for each variant

MODEL	REACTION WHEELS	A (MM)	B (MM)
CW0017	CW0017	67.00±0.5	41.84±0.3
CW0057P	CW0057	73.90±0.5	43.27±0.3
CW0162P	CW0162	90.56±0.5	53.18±0.3
CW500*	TBD	TBD	TBD
CW1200*	TBD	TBD	TBD
CW2000*	TBD	TBD	TBD
CW5000*	TBD	TBD	TBD

* - In development

3.2.2 Mounting definition

A CubeWheel Pyramid can only be mounted on a single side (base), see Figure 12. The base of the pyramid, as shown in Figure 12 and Table 15, has eight (8) M3 x 0.5mm threaded mounting holes that must all be used to ensure adequate fixation of the pyramid to the structure it is fastened to. Note, all dimensions indicated in Table 15 have a tolerance of ± 0.1 mm unless otherwise specified.

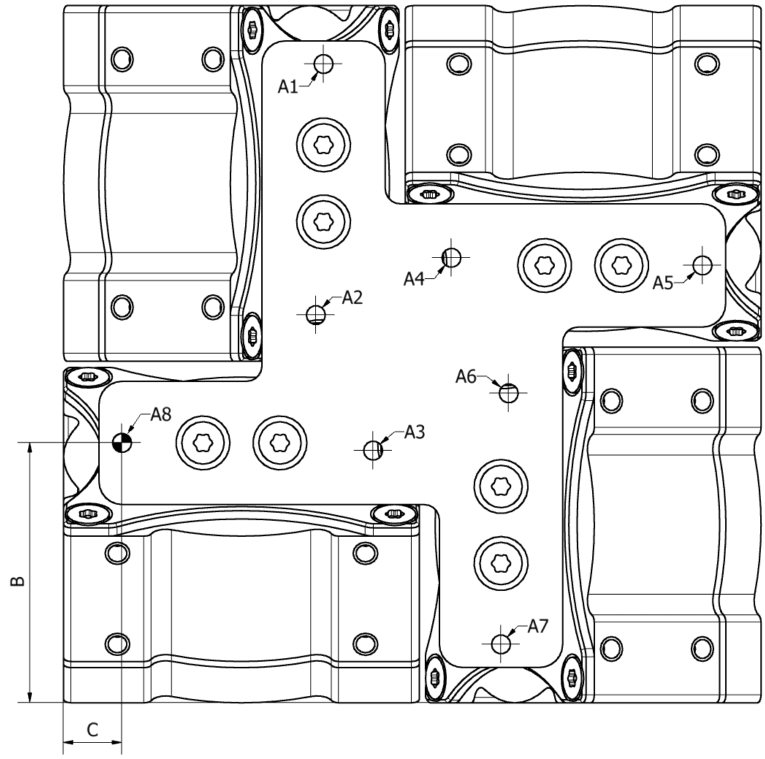

Figure 12: CubeWheel Pyramid Mounting Holes

Table 15:CubeWheel Pyramid mounting hole location values.

MODEL	CW0017P		CW0057P		CW0162P	
	X dim (MM)	Y dim (MM)	X dim (MM)	Y dim (MM)	X dim (MM)	Y dim (MM)
A1	20.35	38.65	26.48	40.42	26.16	49.20
A2	20.35	15.65	24.98	13.92	25.16	16.60
A3	23.00	0.00	26.50	-1.50	32.60	-1.00
A4	36.00	18.30	40.40	15.43	42.76	24.40
A5	59.00	18.30	66.90	13.93	75.36	23.04
A6	38.65	2.65	41.92	0.02	50.20	6.44
A7	38.65	-20.35	40.42	-26.48	49.20	-26.16
A8	0.00	0.00	0.00	0.00	0.00	0.00
B	23.00		29.98		33.76	
C	4.00		3.50		7.60	
Hole Type	M3x0.5 5mm Deep		M3x0.5 4mm Deep		M3x0.5 5mm Deep	

3.2.3 Mass, COM and Inertia

The mass, COM and Inertia of each CubeWheel Pyramid variant are shown in Table 16.

The position of the COM and its respective dimensions L and M are shown in Figure 13.

The reference frame for all dimensions provided in Table 16 is displayed in

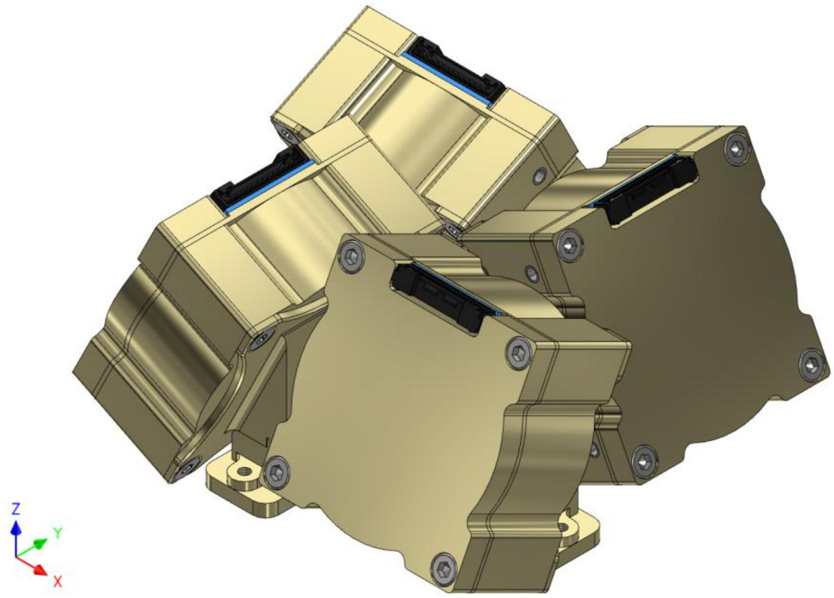

Figure 14.

Table 16: CubeWheel Pyramid mass, COM and inertia for each variant

MODEL	MASS (G)	COM (MM)		INERTIA AROUND COM (GMM²)		
		L	M	I_{xx}	I_{yy}	I_{zz}
CW0017P	236*	17.56	33.50	92623 ± 10%	92623 ± 10%	149070 ± 10%
CW0057P	470	18.68	36.95	224208 ± 10%	224208 ± 10%	360311 ± 10%
CW0162P	704	23.95	45.28	536683 ± 10%	536683 ± 10%	828492 ± 10%

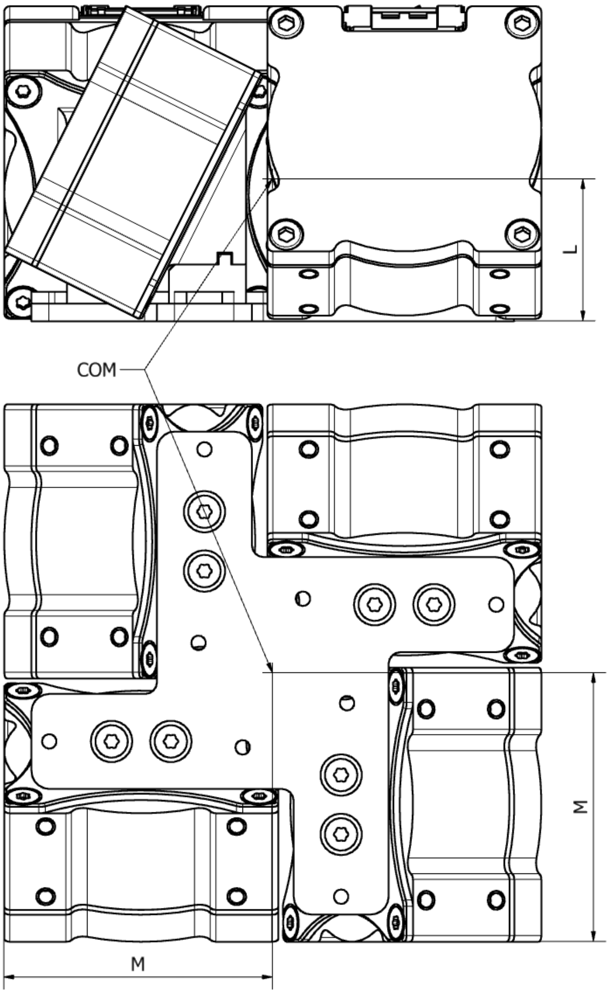

Figure 13: CubeWheel Pyramid COM position

3.2.4 Coordinate System Definition

The coordinate system definition used by the CubeWheel pyramid is shown in

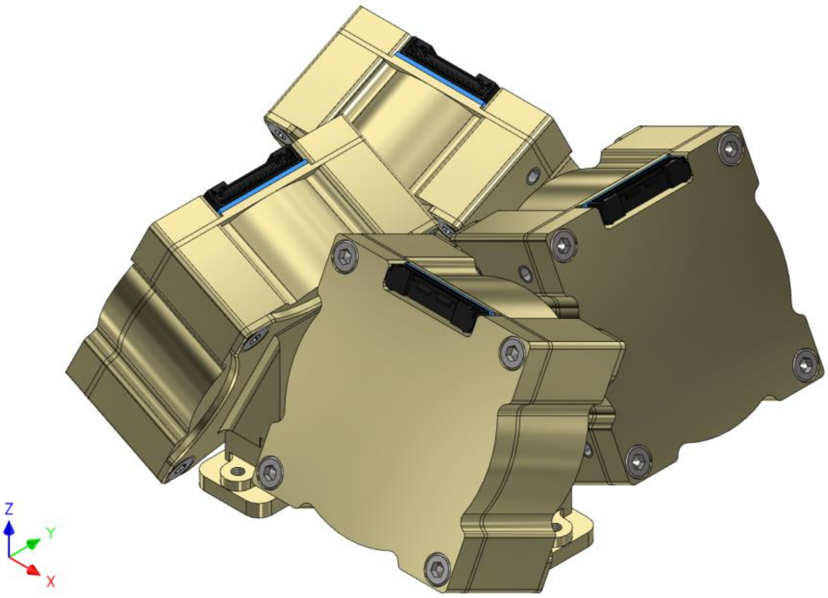

Figure 14. The individual reaction wheel locations relative to the coordinate system definition is shown by the red numbers (A, B, C, D) on each wheel.

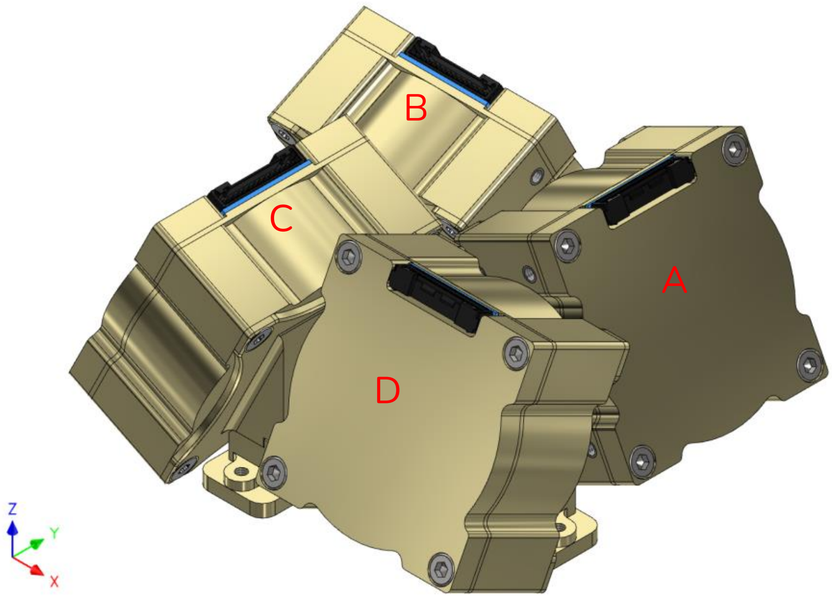

Figure 14: CubeWheel Pyramid coordinate system definition

3.2.5 Electrical Interface

The CubeWheel pyramid interface has four individual/separate interfaces, each the same as defined in section 2.3.1.

4 Mass Summary

Table 17 details the mass of the CubeWheel.

Table 17: CubeWheel mass

CUBEWHEEL	VARIANT/MODEL	MASS (G)[2]	NOTES
CubeWheel	CW0017	52	Measured
	CW0057	101	Measured
	CW0162	144	Measured
	CW0500*	TBD	* - In development
	CW1200*	TBD	* - In development
	CW2000*	TBD	* - In development
	CW5000*	TBD	* - In development
CubeWheel Pyramid	CW0017P*	234	CAD mass
	CW0057P	470	Measured
	CW0162P	704	Measured
	CW0500P*	TBD	* - In development
	CW1200P*	TBD	* - In development
	CW2000P*	TBD	* - In development
	CW5000P*	TBD	* - In development

[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 CubeWheel.

5.1 Potential RF emitter list

Table 18: CubeWheel Potential Emitters

COMPONENT	EMITTER TYPE	FREQUENCY	FREQ. STABILITY
MCU	Crystal	24 MHz	± 50 ppm
Comms UART	-	921.6 kHz	± 50 ppm
Comms I2C	-	100 kHz	± 50 ppm
Comms CAN	-	500 kHz	± 50 ppm
SPI	-	24 MHz	± 50 ppm
Motor driver PWM	-	6 kHz	± 50 ppm
Motor Driver oscillator 1	LC	51.5 kHz	± 10 kHz
Motor Driver oscillator 2	-	103 kHz	± 21 kHz

5.2 Minimising EMI / EMC effects

5.2.1 Grounding

The enclosure and mechanical parts of CubeWheel are connected to the electrical ground through a filter designed to minimise EMI, as illustrated by Figure 15. (Note that a generic CubeADCS diagram is shown to explain the grounding strategy followed, for consideration by the client). The enclosure of the CubeWheel can be grounded by the user if desired.

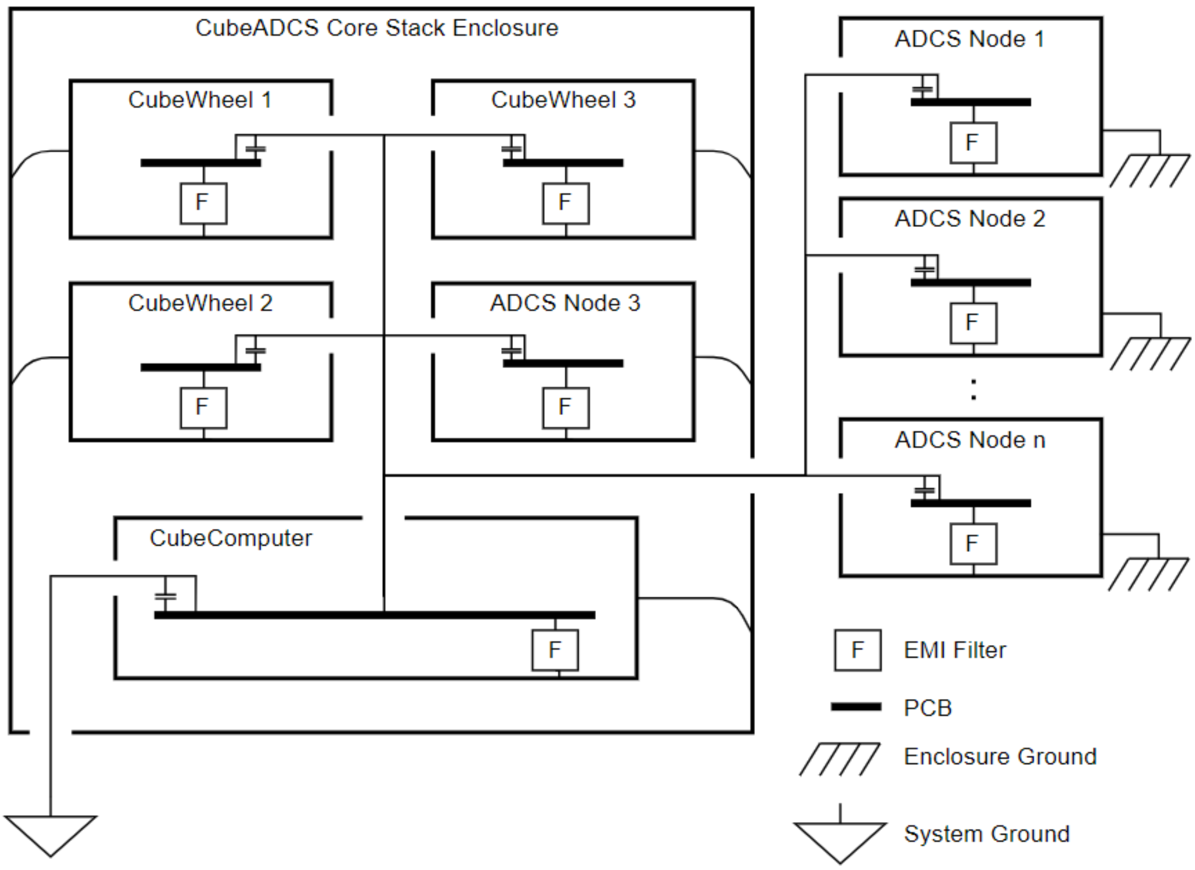

Figure 15: Generic Grounding diagram

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 CubeWheel 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 CubeWheel 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.

5.2.3 Harness pairing of conductors and twisting.

The wires of the harnesses provided by CubeSpace for the CubeWheel form twisted pairs as indicated in Table 19 below.

Table 19: Twisted Wire Pairs on Harness

PIN 1	PIN 2	COMMENT
3V3	GND	
Enable	GND	
Boot	GND	

PIN 1	PIN 2	COMMENT
$V_{Battery}$	GND	Only for CubeWheels
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 16 below shows an example image of a final flight harness.

Figure 16: Flight harness example

5.2.4 *Filtering and Suppression*

The following noise filtering schemes are utilised on the CubeWheel:

a. All pins that are externally exposed through headers are filtered by way of 100pF decoupling to ground as shown in Figure 15.
b. LC filtering is done on the CubeComputer's external 5V and 3.3V power supply input lines.
    a. For the standalone CubeWheel, 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.
    a. For the standalone CubeWheel, 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).
    a. For the standalone CubeWheel, 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.
    a. For the standalone CubeWheel, the client is requested to consider implementing similar on the client ADCS / OBC side – details can be provided.

5.2.4.1 *Battery Power Rail Filtering*

A pre-filter is in place for the satellite battery supply to the CubeComputer. This ensures that noise on this power rail will be minimized before entering the CubeADCS and will also reduce/minimized noise generated by the CubeADCS to be emitted onto the power rail.

For the standalone CubeWheel, 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 CubeWheel. 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 mid 2023 is targeted. This chapter will then be updated accordingly documenting the formal qualification status of the CubeWheel.

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 CubeWheel, 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 CubeWheel. The CubeWheel 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.

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

The CubeWheel, while not powered, is subjected to a cold start temperature of -35 degC. Once the soak period of minimum 30 minutes has passed, the CubeWheel is powered up and its start-up sequence is monitored for correct operation and if successful, a brief health check is done. The CubeWheel is then powered down and temperature raised to +70 degC and the power up sequence and brief heath check is repeated. The CubeWheel is again powered down and brought back to ambient temperature. A complete Acceptance test Procedure (ATP) is then conducted and if all tests pass, the CubeWheel 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 cycles (for both hot and cold extremes – see tables below) the CubeWheel is subjected to a full health check test procedure. Once all cycles have been completed, the CubeWheel is subjected to a full ATP. If the CubeWheel passes all tests, it is deemed to have passed TVAC testing at qualification levels.

Table 20: TVAC Hot 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

TVAC PARAMETER	TEST LEVEL
Temperature Tolerance	±2 °C
Temperature ramp rate	1 °C/min
Maximum Temperature (Qualification)	+80±2°C

Table 21: 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 CubeWheel, 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 CubeWheel is subjected to a full ATP. If the CubeWheel passes all tests, it is deemed to have passed Vibration testing at qualification levels.

Table 22: 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 23: Qualification sine plus quasi-static levels

FREQUENCY (HZ)	AMPLITUDE (G) [0-PK]
5	1
10	2.5
21	2.5
25	15
30	15
35	3
110	3
125	0.25

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

Table 24: -3dB random vibration qualification levels

FREQUENCY (HZ)	AMPLITUDE (G²/HZ)
20	0.0282
50	0.0802
800	0.0802
2000	0.0130
Duration	60 seconds
Grms	10.02

Table 25: Random vibration qualification levels

FREQUENCY (HZ)	AMPLITUDE (G²/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 CubeWheel, 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 CubeWheel is subjected to a full ATP. If the CubeWheel passes all tests, it is deemed to have passed Shock testing at qualification levels.

Table 26: 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 CubeWheel and is optionally available from CubeSpace and should be specifically requested during order placement.