CUBESPACE

Interface Control Document

CubeWheel: NanoSat Range

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1.01	J. Miller	14/07/2023	Update to Table 18
1.02	J. Miller	10/10/2023	Update torque graphs and tables.
1.03	J. Miller	13/02/2025	Moved data to Technical reference Manual [RD3]. Common ICD changes implemented. Updates to reflect CubeWheel grouping into NanoSat and SmallSat ranges, this document becomes more specifically for the CW NanoSat range.
1.04	J. Miller	04/03/2025	Updated CW0500 Power Parameters.

Reference Documents

The following documents are referenced in this document.

[RD1] CS-DEV.PD.CW-01 CubeWheel Product Description Ver.1.00 or later
[RD2] CS-DEV.UM.CW-01 CubeWheel User Manual Ver.1.00 or later
[RD3] CS-DEV.REF.CW-01 CubeWheel CubeSat Technical Reference Manual Ver.1.00 or later
[RD4] CS-DEV.ETP.CA-01 Generic Environmental Test Plan Ver.1.05 or more recent
[RD5] CS-DEV.FRM.CA-01 CubeProduct Firmware Reference Manual Ver 7.02 or later

List of Acronyms/Abbreviations

ADCS	Attitude Determination and Control System
CAN	Controller Area Network
CoM	Centre of Mass
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FM	Flight Model
I2C	Inter-Integrated Circuit
MCU	Microcontroller Unit
OBC	On-board Computer
PCB	Printed Circuit Board
PTFE	Polytetrafluoroethylene
RF	Radio Frequency
RWL	Reaction Wheel
UART	Universal Asynchronous Receiver/Transmitter

Table of Contents

Table of Tables

Table of Figures

1. Introduction

The purpose of this document is to provide information on how to correctly interface with CubeWheel. This includes communications, power requirements, mechanical mounting and axes definitions, as well as guidelines on EMI/EMC compatibility. It is assumed that the reader is already familiar with the relevant product description document [RD1]. Details regarding environmental qualification, and a declared materials list, are available to clients upon request.

CubeSpace cannot guarantee nominal operation of CubeWheel if the specifications provided in this document are not adhered to.

The CubeWheel sizes have been grouped into two ranges based on their momentum storage capability, namely the Nanosat range and SmallSat range. This ICD applies to the products and hardware versions of the NanoSat range, listed in Table 1.

Table 1: Document Applicability

CubeProduct	Wheel Size	Version	Notes
CubeWheel NanoSat Range	CW0017, CW0057, CW0162	M2.0E2.3	-
	CW0500	M2.1E1.3	-

2. Electrical Interface

2.1 Communication Interfaces

2.1.1 CAN Characteristics

Table 2: CAN Bus Characteristics

Parameter	Value
Supported CAN standard	V2.0B
Supported bit rate	1 Mbit/s
Supported protocols	CubeSpace CAN Protocol, CubeSat Space Protocol (CSP)
Default CAN address	4 (configurable)
CAN termination	2 kΩ

2.1.2 UART/RS485 Characteristics

If necessary, RS485 can be chosen instead of UART when placing the order. In this case UART will be unavailable, and the ability to upgrade or reflash the software bootloader will be lost.

Table 3: UART/RS485 Characteristics

Parameter	Value
Maximum supported baud rate	921600 (configurable)
Data bits	8
Parity	None
Stop bits	1
RS485 address	1 (configurable)
RS485 termination	1 kΩ

2.1.3 I2C Characteristics

I2C communication is not available on all CubeWheels. Where it is available, CubeWheel is always configured as 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.

Table 4: I2C Characteristics

Parameter	Value
Supported CubeWheels	CW0017, CW0057, CW0162
Maximum supported bit rate	1 Mbit/s (I2C Fast Mode Plus)

Parameter	Value
Addressing mode	7-bit configurable slave address
Clock stretching	Yes (master must support clock stretching)
Repeated-start support	Not supported
Default 7-bit Address	0x68

2.1.4 Boot Line

CubeWheel implements a boot line for accessing the MCU's low-level ROM bootloader. The boot line must be pulled high prior to power-on to access the ROM bootloader. It is used by CubeSpace to initially flash the CubeSpace software bootloader to the MCU, thereafter the software bootloader is used for uploading flight software. The client can leave this pin unconnected, however it is recommended to connect it to the ADCS/OBC as a recovery method in case the software bootloader needs to be updated or re-flashed.

If necessary, RS485 can be chosen instead of UART when placing the order. In this case UART will be unavailable, and the ability to upgrade or reflash the software bootloader will be lost.

2.2 Power Interface

The typical power characteristics are independent of the satellite's size or control mode being used.

Table 5: External Power Supply Requirements

External power	CW0017	CW0057	CW0162	CW0500
Digital Supply Voltage [V]	3.3	3.3	3.3	3.3
Motor Supply Voltage Range (V_{bat}) [V]	6.4-16.8	6.4-16.8	6.4-16.8	6.4-24
Nominal Motor Supply Voltage [V]	8	12	12	12

Table 6: Power Consumption on 3.3 V Line

Parameter	Value	Notes
Average current	32 mA	Measured for all wheel variants.
Average power	106 mW	
Max current	79 mA	
Max power	261 mW	
Inrush current	270 mA	
Inrush current duration	5 µs	

2.2.1 Enable Line

CubeWheel implements an externally controlled enable line to power on the device. The enable line is active-high and should be controlled by the client ADCS/OBC.

2.2.2 3.3 V Power Switch

CubeWheel implements an input power switch on the 3.3 V line that is enabled by pulling the enable line high. The power switch also provides a current limit of 400 mA to protect against latch-up events. Under- and overvoltage protection is also implemented, with a range of 2.5 V – 3.9 V depending on thermal conditions.

2.2.3 Client ADCS/OBC Power Protection Requirements

It is recommended that the client ADCS/OBC implements voltage monitoring on the 3.3 V line to CubeWheel to ensure that it is always within the range specified in Table 5: External Power Supply Requirements. It is also recommended that the client ADCS/OBC implements current limiting on the 3.3 V line to CubeWheel to mitigate the effects of a latch-up in the case of a fault.

2.2.4 Power and Signal Ground

CubeWheel does not have separate power and signal ground, all circuits share the same ground.

2.3 CubeWheel Power Characteristics

To achieve the maximum rotation speed and thus momentum storage, the wheels require a minimum battery supply voltage, as defined in Table 5. Lower battery supply voltages will result in a correspondingly lower momentum storage capacity. Similarly, a minimum current is required to achieve the maximum torque; less powerful supplies will achieve a correspondingly lower maximum torque from the wheels.

2.3.1 Power Consumption on the Battery Voltage Rail

The CubeWheels (as reaction wheels) facilitate rotating a spacecraft to a required attitude, and for maintaining a desired attitude by counteracting in-orbit disturbance torques. The power consumption of reaction wheels depends on the running speed and the torque demand. The maximum current and power characteristics are provided in Table 7, but more current draws at different momentum levels and torques are provided in [RD3].

Table 7: Power Consumption on Battery Voltage Rail

CubeWheel Variant	Power at rated momentum [W]	Max current[1] at 12V [mA]	Peak power[2] [W]
CW0017	0.3	370	0.85
CW0057	0.77	656	2.7
CW0162	0.77	952	7.2
CW0500	3.4	1250	15

The CubeWheel design has been optimized to minimize inrush current demand on the battery supply, characteristics of which are given in Table 8. Two primary instances of inrush current are identified: the first occurs when the battery supply to the wheels is enabled by the power distribution system, and the second

[1] The maximum current is drawn in short pulses at 24 kHz, the frequency of the motor driver PWM.

[2] The peak power is defined as the maximum power drawn when the wheel accelerates through rated momentum speed at the nominal torque, including both battery and digital power components.

occurs upon activation of the motor power. It is important to note that activation of motor power is an internal function, triggered either automatically or via telecommand.

Table 8: Battery Inrush Current Characteristics

Model	Nominal Supply voltage [V]	Inrush Current [mA]	Duration [mS]	Instance
CW0017	8.0	110	0.04	Power Supply Enable
CW0057	12.0	110	0.08	Power Supply Enable
CW0162	12.0	110	0.08	Power Supply Enable
CW0500	12.0	2280/720	0.140/12	Power Supply Enable/Motor Power Enable

2.3.2 Battery Voltage Power Switch

There is overvoltage protection on the V_{bat} bus line. If V_{bat} falls outside the range specified in Table 5: External Power Supply Requirements, power to the motor driver will be automatically switched off.

Table 9: Battery Voltage Input Power Switches

CubeWheel Variant	V_{bat} Input Protection Cutoff	V_{bat} Circuit Damage Limit
CW0017, CW0057, CW0162	See Table 5.	20 V
CW0500	See Table 5.	40 V

2.4 Header Pinout and Electrical Characteristics

Table 10: Header Part details

Part	Description	Part Number
Header	Molex Micro-Lock Plus PCB Header	5055671081
Mating housing	Molex Micro-Lock Plus Receptacle Crimp Housing	5055651001
Housing terminal	Molex Micro-Lock Female Crimp Terminal	5054311100

Table 11: Header Pinout and Electrical Characteristics

Pin #	Pin Name	Pin Description	IO Type	Voltage range [V]
1.	Boot	Toggle ROM bootloader on startup Active-high Leave disconnected if unused	Input	0 to 3.4
2.	I2C SDA[3] /GND	I2C bus data Line/ Power and signal ground*	Input	2.7 to 5.5V
3.	3V3	Digital supply voltage	Power	3.2 to 3.4
4.	UART_TX	UART data transmit line (default)	Output	0 to 3.4
	RS485 A	RS485 A (alternative)	Bidirectional	

[3] For the CW0500 where I2C is not available Pin 2 and Pin 9 are connected to GND.

Pin #	Pin Name	Pin Description	IO Type	Voltage range [V]
5.	CAN_H	High level CAN bus line	LVDS	0 to 3.4
6.	CAN_L	Low level CAN bus line	LVDS	0 to 3.4
7.	UART Rx	UART data receive line (default)	Input	0 to 3.4
	RS485 B	RS485 B (alternative)	Bidirectional	
8.	GND	Power and signal ground	Power	0
9.	I2C SCL[3] /GND	I2C bus clock line	Input	2.7 to 5.5V
10.	Enable	Toggle power on Active-high	Input	-0.5 to 3.4
11.	GND	Power and signal ground	Power	0
12.	GND	Power and signal ground	Power	0
13.	VBAT	Supply voltage for motor driver	Power	Refer to Table 5 [4]
14.	VBAT	Supply voltage for motor driver	Power	Refer to Table 5 [4]

2.5 Harness Details

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 a standard FM pigtail harness that can be used by the client to assemble a flight harness. The standard FM pigtail harness specifications are described in Table 12. The standard length can be cut shorter, and longer (custom) lengths can be arranged during order placement.

The EM harness is provided as part of the ground support equipment package only and is not low-outgassing. Therefore, it is not safe for flight or for use in a vacuum.

Table 12: Harness Details

Harness	No. Wires	Wire Gauge (AWG)	Wire mass (kg/km)	Housing mass (mg)	Terminal mass (mg)	Total Mass
FM pigtail	14	26	1.96	263.5	35.434	Length Dependant

2.6 CubeWheel Pyramid Electrical Interface

The CubeWheel pyramid has four separate electrical interfaces, one for each reaction wheel, each the same as defined in section 2.4.

[4] The voltage applied to the motor determines the maximum steady state speed.

3. Mechanical Interface

CubeWheels are offered as single wheels (usually 3 wheels as an XYZ configuration), and in a 4-wheel pyramid configuration which offers increased performance and redundancy. This section of the ICD presents standalone wheels first, and then wheels as a pyramid assembly.

3.1 Standalone CubeWheels

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.

3.1.1 Outer Dimensions

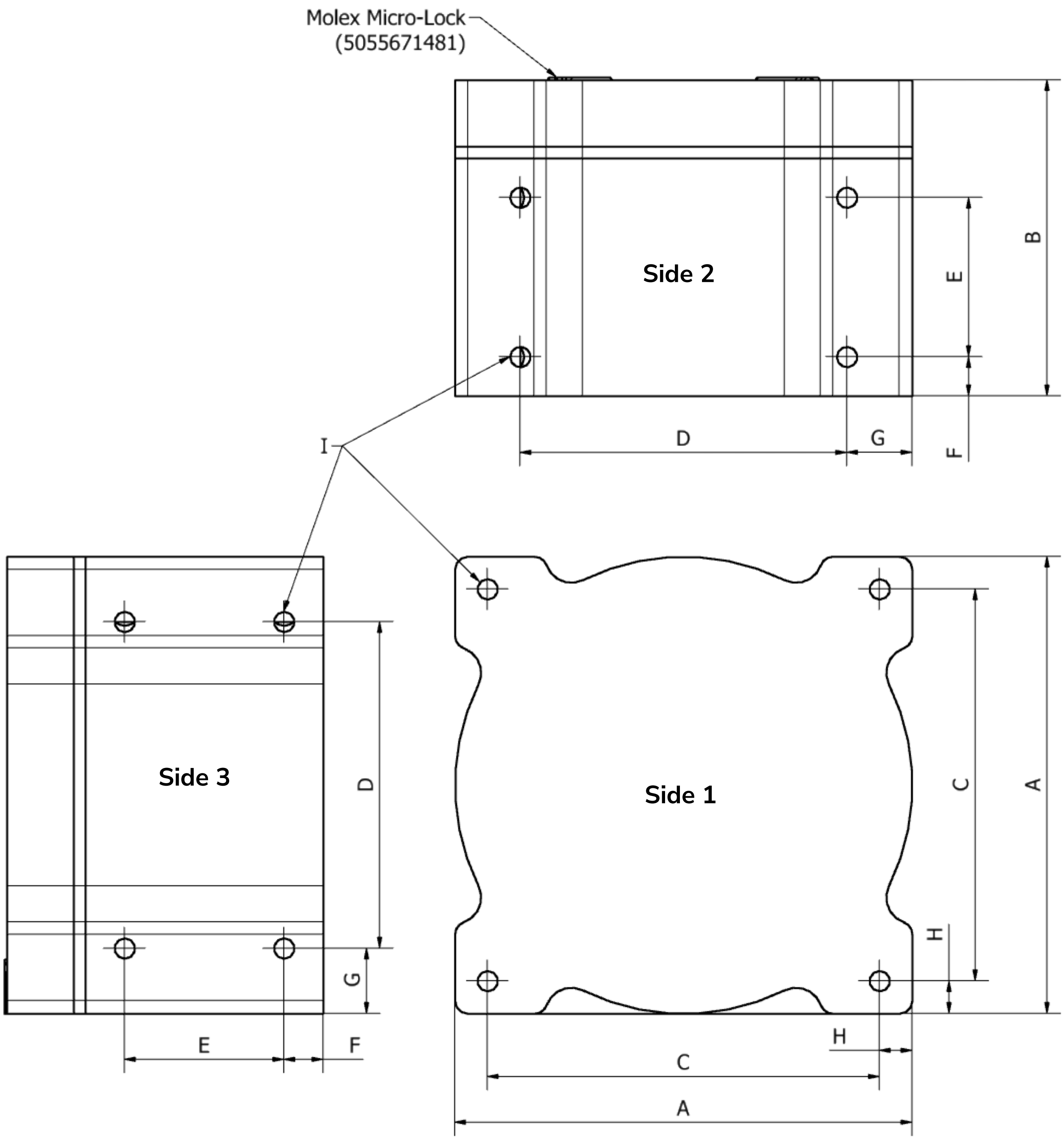

Figure 1: Indicative Dimensions of CubeWheel

The dimensions given in this chapter are indicative only. The mechanical CAD files with the latest dimensions are supplied to customers and must be used for final design and fitment verification.

Table 13: CubeWheel Dimensions

Model	A (mm)	B (mm)	C (mm)	D (mm)	E (mm)	F (mm)	G (mm)	H (mm)	I
CW0017	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 4.0 Deep
CW0057	35.0±0.1	24.2±0.2	30.0±0.1	25.0±0.1	12.2±0.1	3.0	5.0	2.5	M2x0.4 4.0 Deep
CW0162	46.2±0.1	24.2±0.2	39.8±0.1	32.2±0.1	13.2±0.1	2.5	7.0	3.2	M3x0.5 4.5 Deep
CW0500	66.0±0.1	26.0±0.2	56.8±0.1	45.5±0.1	11.5±0.1	2.75	10.25	4.6	M4x0.7 6.0 Deep

3.1.2 Mounting Definition

Each CubeWheel has three orthogonal faces with four mounting holes on each face, see Figure 1: Indicative Dimensions of CubeWheel. 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 mounting structure can easily result in vibration amplification that could damage the wheel bearings. Fasten the wheels using a torque wrench according to Table 14 below. Ensure that all mounting screws are staked using non-outgassing adhesive before conducting vibration tests.

Table 14: Recommended Mounting Screw Torques

Product	Mounting Hole	Recommended Torque [cN.m]
CW0017, CW0057	M2 threaded aluminium.	26
CW0162	M3 threaded aluminium.	87
CW0500	M4 threaded aluminium.	207

3.1.2.1 Mounting Relief Cut-out (CW0500 Only)

For certain CW0500 mounting configurations, a relief cut-out in the mounting surface is required to ensure proper behaviour of the internal damping.

A relief cut in the mounting surface is needed for mounting CW0500 on side 2 or side 3, as in Figure 1: Indicative Dimensions of CubeWheel. The relief cut details are shown in Figure 2, and dimensions in given Table 15.

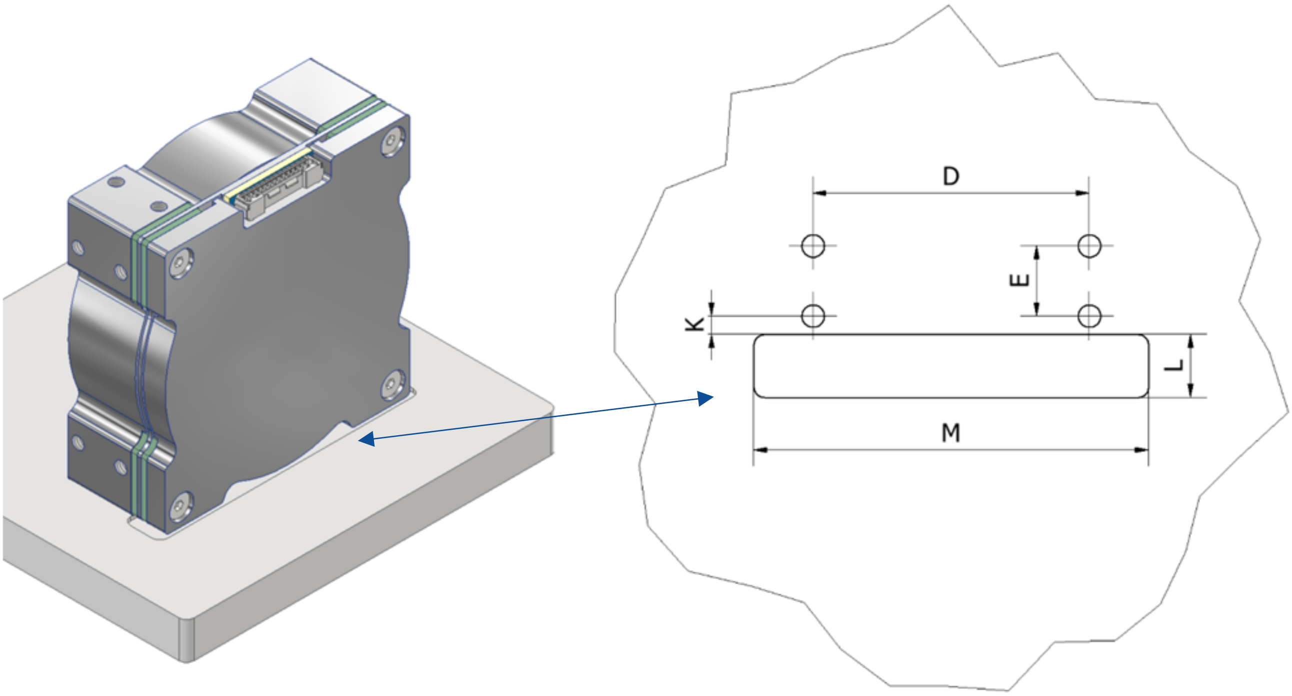

Figure 2: CW0500 Mounting Surface Relief Cut

Table 15: CW0500 Mounting Surface Relief Cut Dimensions

CubeWheel Variant	K (mm)	L (mm)	M (mm)	Relief Depth (mm)	Corner Radius (mm)
CW0500	2.50	10.0	70.0	1.0	2.0

3.1.3 Mass, CoM and Inertia

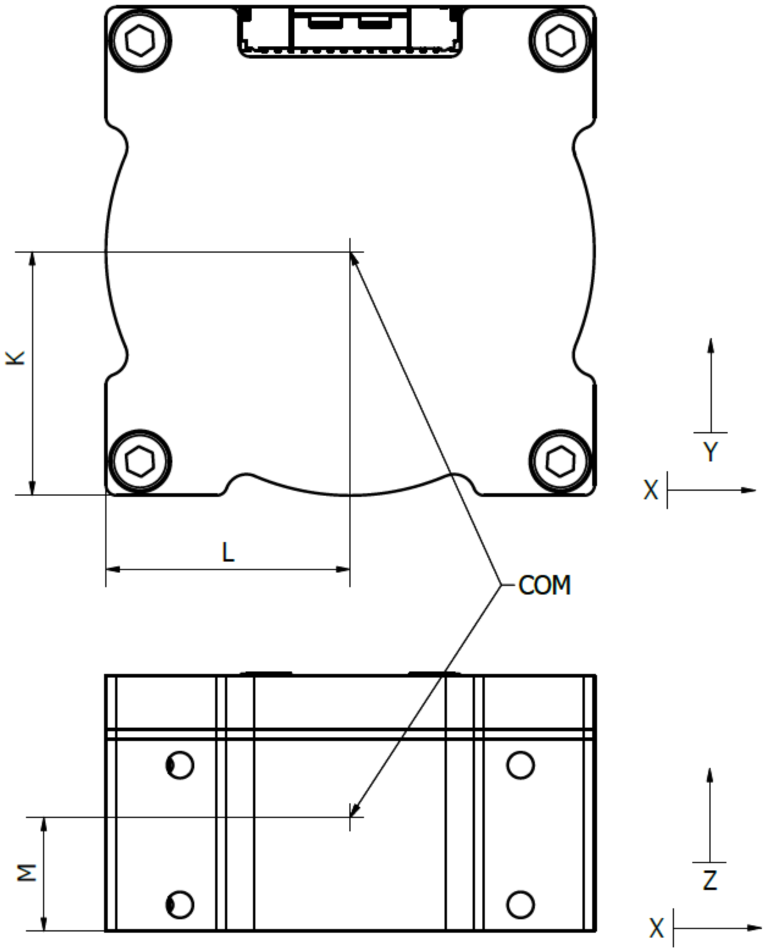

Figure 3: CoM Position of CubeWheel

Specific dimensions for interpreting Figure 3 are given in Table 16, along with 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 axes definition for interpreting MoI is provided in Figure 4: CubeWheel Coordinate System Definition.

Table 16: Mass, CoM and Inertia Details

Model	Mass (g)	CoM (mm)			Inertia around CoM (gmm²)			Flywheel inertia (gmm²)
		K	L	M	I_{xx}	I_{yy}	I_{zz}	
CW0017	52	14.12	13.62	12.24	5398 ± 10%	5618 ± 10%	6317 ± 10%	2128
CW0057	105	17.36	17.51	9.89	12894 ± 10%	12774 ± 10%	18389 ± 10%	9510
CW0162	144	23.04	23.08	10.78	32021 ± 10%	31873 ± 10%	52100 ± 10%	25997
CW0500	322	33.12	33.08	11.98	125824 ± 10%	125367 ± 10%	220680 ± 10%	82988

3.1.4 Coordinate System Definition

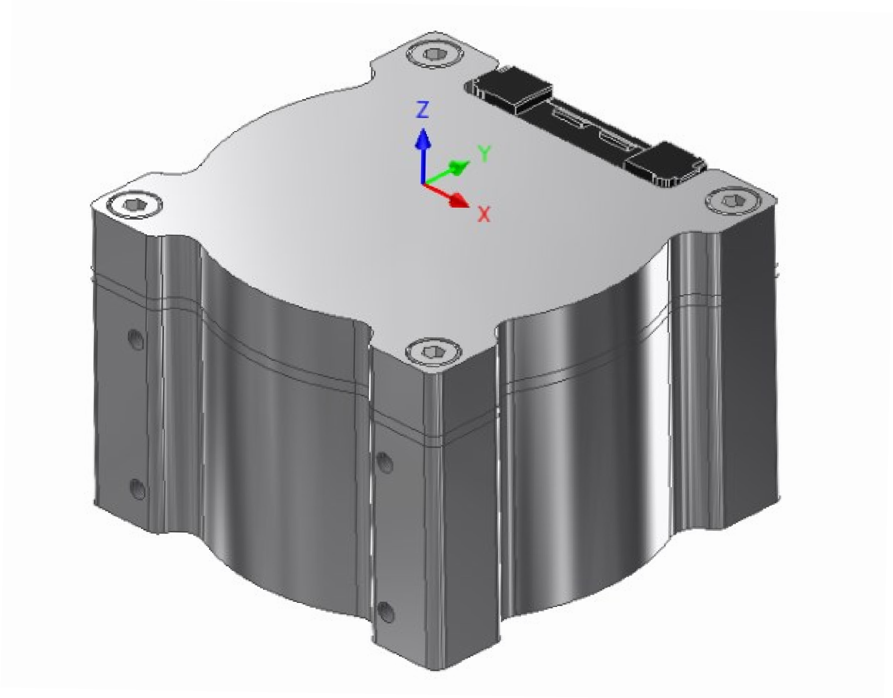

Figure 4: CubeWheel Coordinate System Definition

A positive rotation, resulting from a positive wheel speed reference command or torque command, can be translated to an angular momentum vector pointing out of the top of CubeWheel as shown in Figure 5.

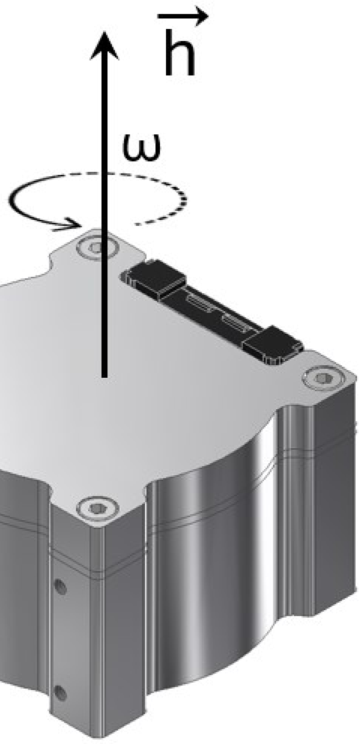

Figure 5: CubeWheel Momentum Definition

3.2 CubeWheel Pyramid

The CubeWheel pyramid consists of four CubeWheels 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

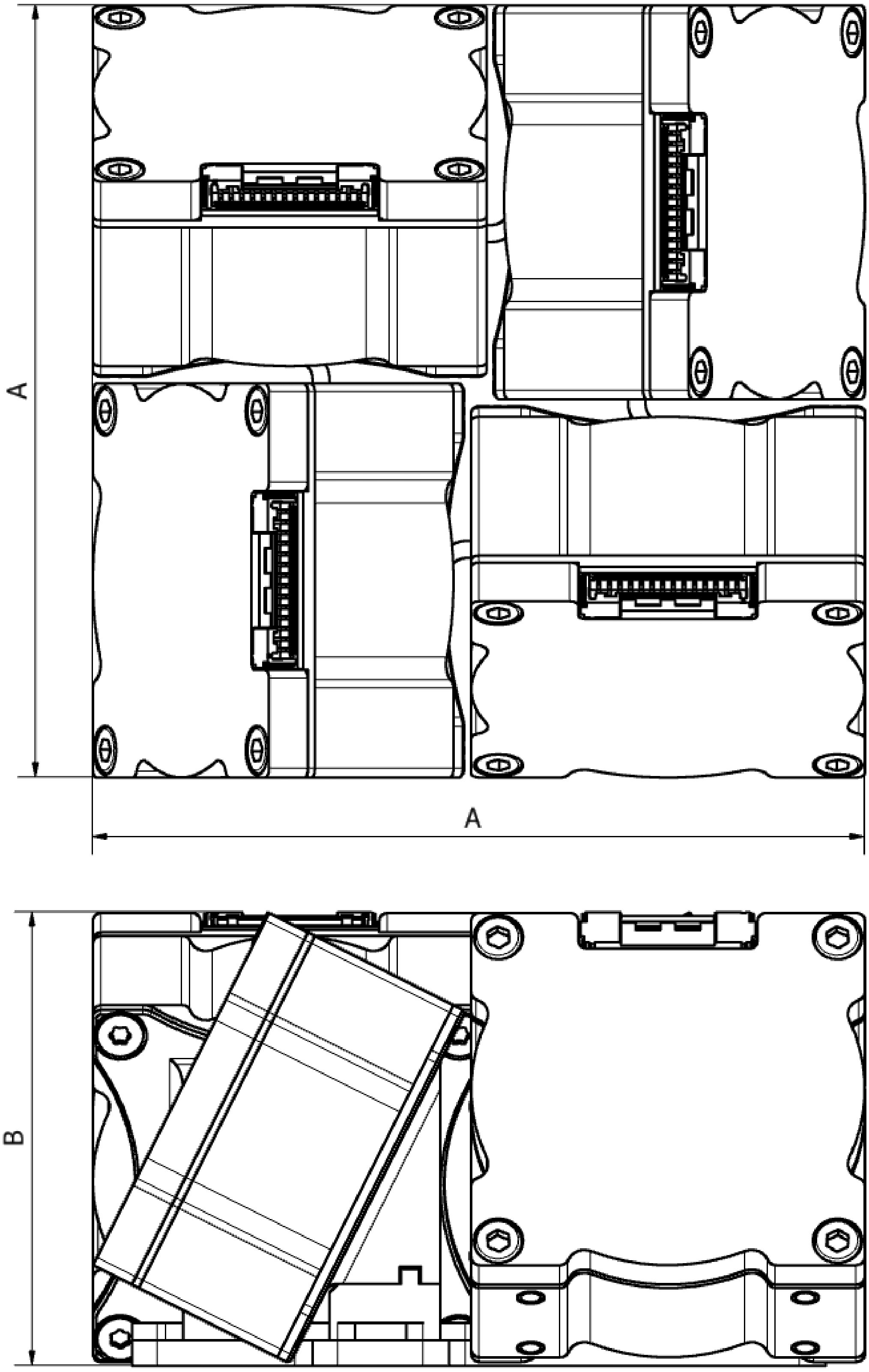

Figure 6: Indicative Dimensions of a CubeWheel Pyramid Assembly

The dimensions shown in Figure 6 for each CubeWheel pyramid configuration are provided in Table 17.

Table 17: CubeWheel Pyramid Dimensions

Pyramid Model	Reaction Wheels	A (mm)	B (mm)
CW0017P	4x CW0017	67.00±0.5	41.84±0.3
CW0057P	4x CW0057	73.90±0.5	43.27±0.3
CW0162P	4x CW0162	90.56±0.5	53.18±0.3
CW0500P	4x CW0500	119.30±0.5	72.57±0.3

3.2.2 Mounting Definition

CubeWheel Pyramid can only be mounted on its base. The pyramid base, shown in Figure 7 and dimensioned in Table 18, has eight (8) threaded mounting holes. All mounting holes **must** be used be used to ensure adequate fixation of the pyramid to the mounting structure.

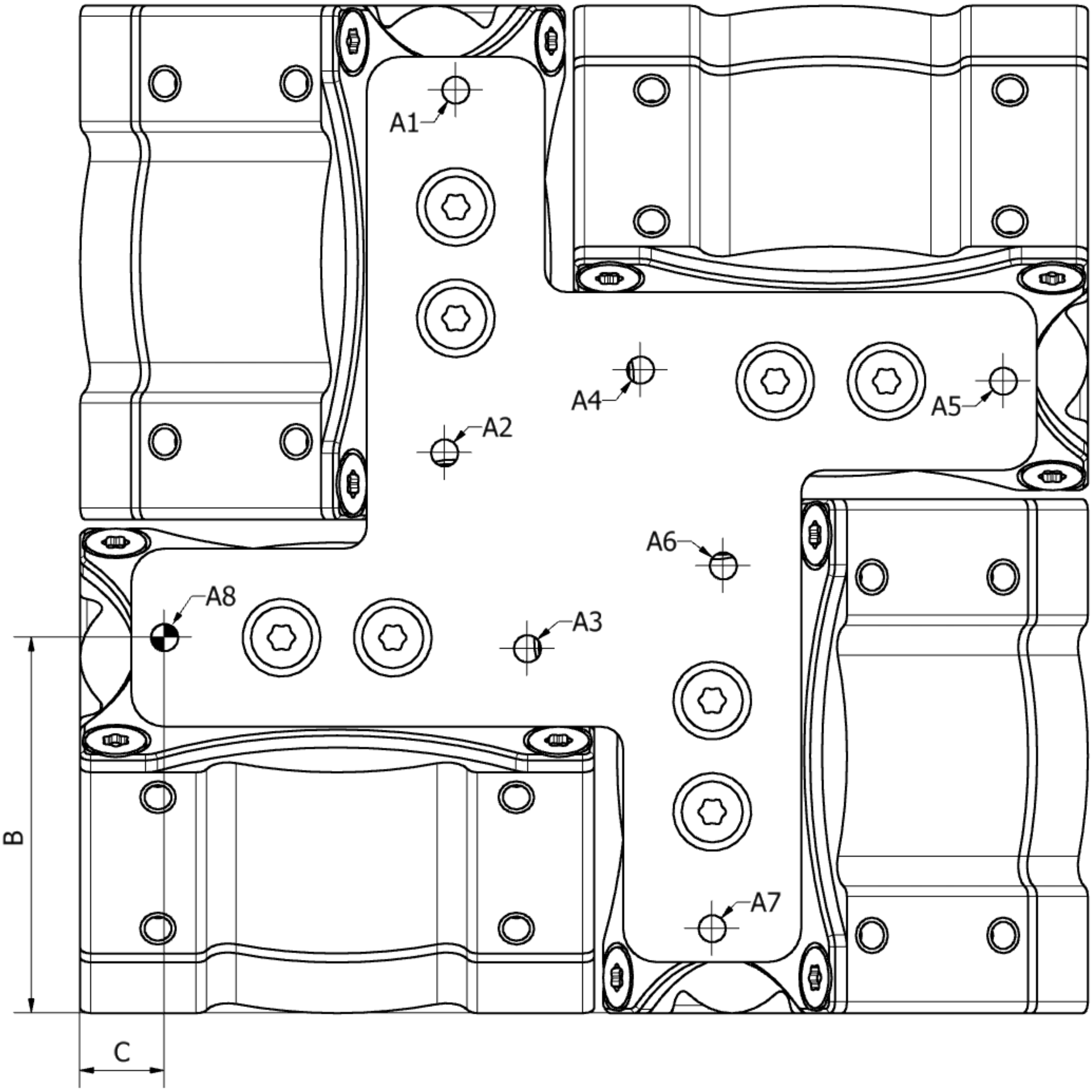

Figure 7: Indicative Dimensions of the CubeWheel Pyramid Base

Table 18: CubeWheel Pyramid Base Mounting Hole Locations for Figure 7

Marker	CW0017P		CW0057P		CW0162P		CW0500P	
	X dim (mm)	Y dim (mm)	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	17.21	72.59
A2	20.35	15.65	24.98	13.92	25.16	16.60	17.21	35.79
A3	23.00	0.00	26.50	-1.50	32.60	-1.00	36.80	0.00
A4	36.00	18.30	40.40	15.43	42.76	24.40	53.00	55.38
A5	59.00	18.30	66.90	13.93	75.36	23.04	89.80	55.38
A6	38.65	2.65	41.92	0.02	50.20	6.44	72.59	19.59
A7	38.65	-20.35	40.42	-26.48	49.20	-26.16	72.59	-17.21
A8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	23.00		29.98		33.76		32.21	
C	4.00		3.50		7.60		14.60	
Hole Type	M3x0.5 5mm Deep		M3x0.5 4mm Deep		M3x0.5 5mm Deep		M4x0.7 10mm Deep	
All dimensions have a tolerance of ± 0.1 mm unless otherwise specified.								

3.2.3 Mass, CoM and Inertia

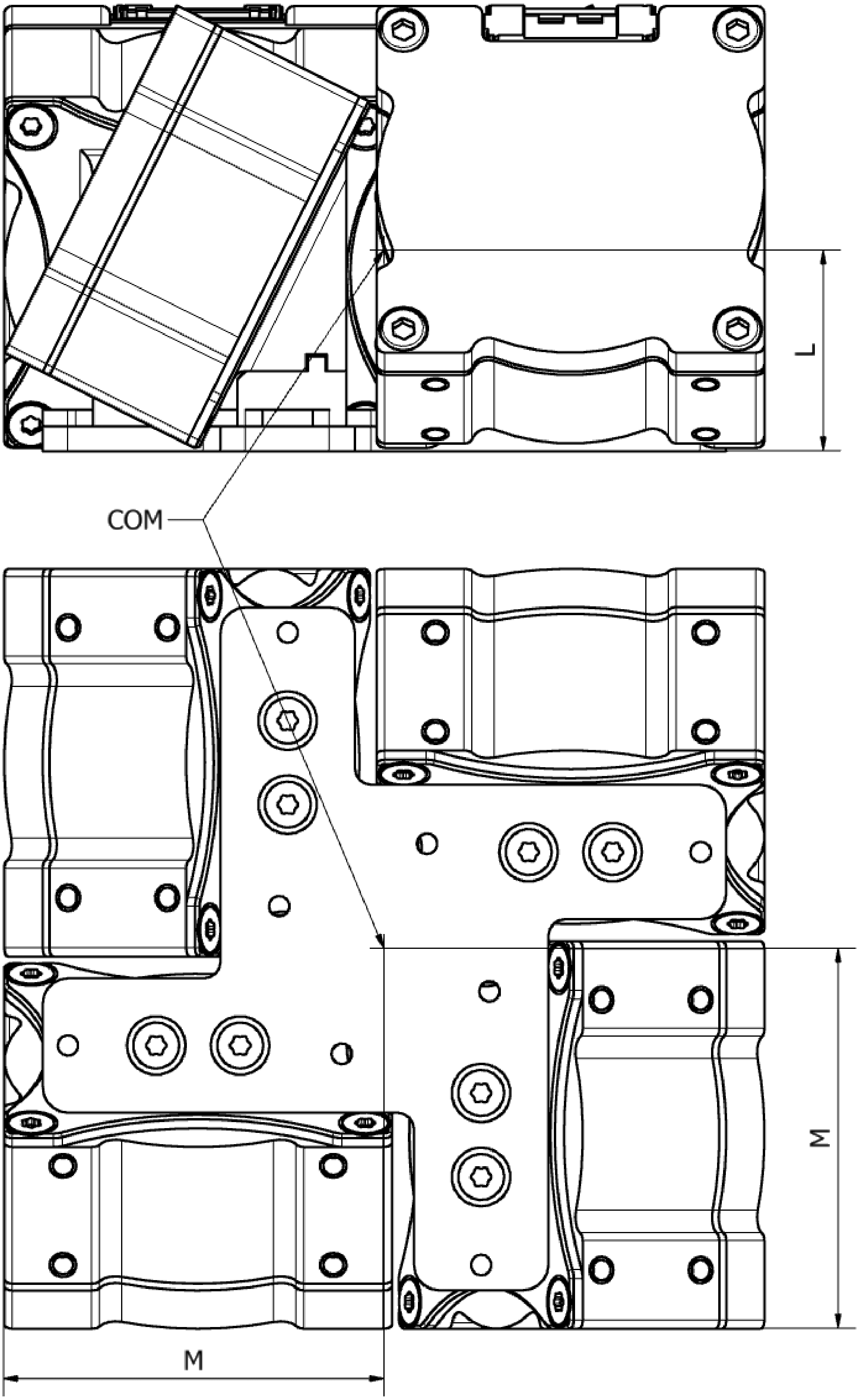

Figure 8: CubeWheel Pyramid CoM position

The position of the CoM as shown in Figure 8 is given by the dimensions in Table 19.

Table 19: CubeWheel Pyramid Mass, CoM and Inertia

Variant	Mass (g)	CoM (mm)		Inertia around CoM (gmm^2)		
		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%
CW0500P	1424	35.107	59.50	2036996 ± 10%	2036996 ± 10%	3070937 ± 10%

3.2.4 Coordinate System Definition

The coordinate system definition used by the CubeWheel pyramid is shown in Figure 9. The individual reaction wheels (shown by the red letters A, B, C, D) also have their locations engraved onto the pyramid bracket.

When the pyramid is used with a CubeSpace ADCS, the CubeComputer configuration is typically set up in a manner that RWL0, 1, 2, 3 refers to wheel “A”, “B”, “C”,” D”, respectively.

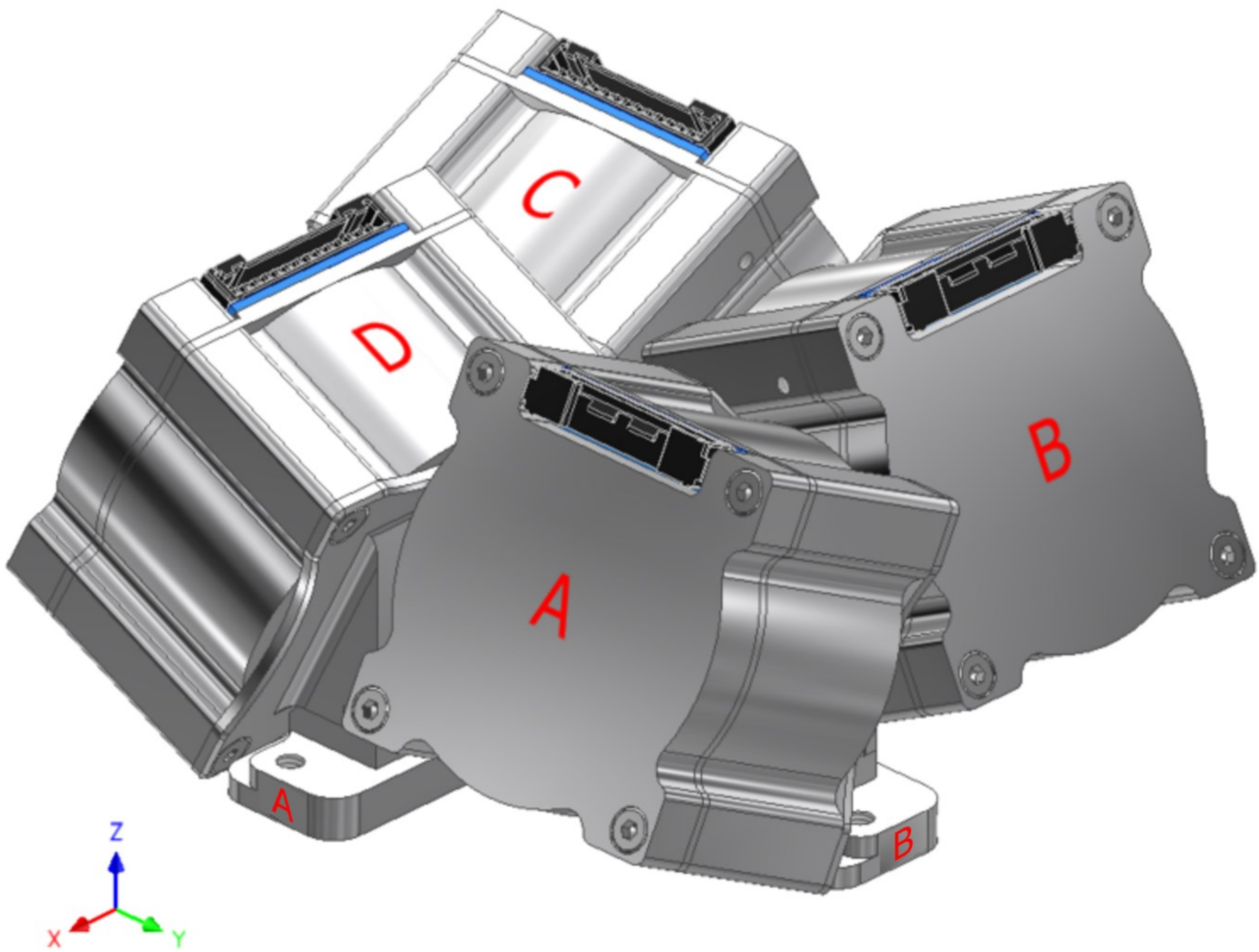

Figure 9: CubeWheel Pyramid Coordinate System Definition

3.2.5 CubeWheel Pyramid Vibration Isolation

Development is progressing on an isolated and non-isolated solution of the CubeWheel pyramid. The isolated pyramid will reduce any transfer of micro-vibrations from the reaction wheels onto the satellite. Contact CubeSpace for product availability and preliminary mechanical drawings. An example of a regular and damped pyramid assembly is presented in Figure 10.

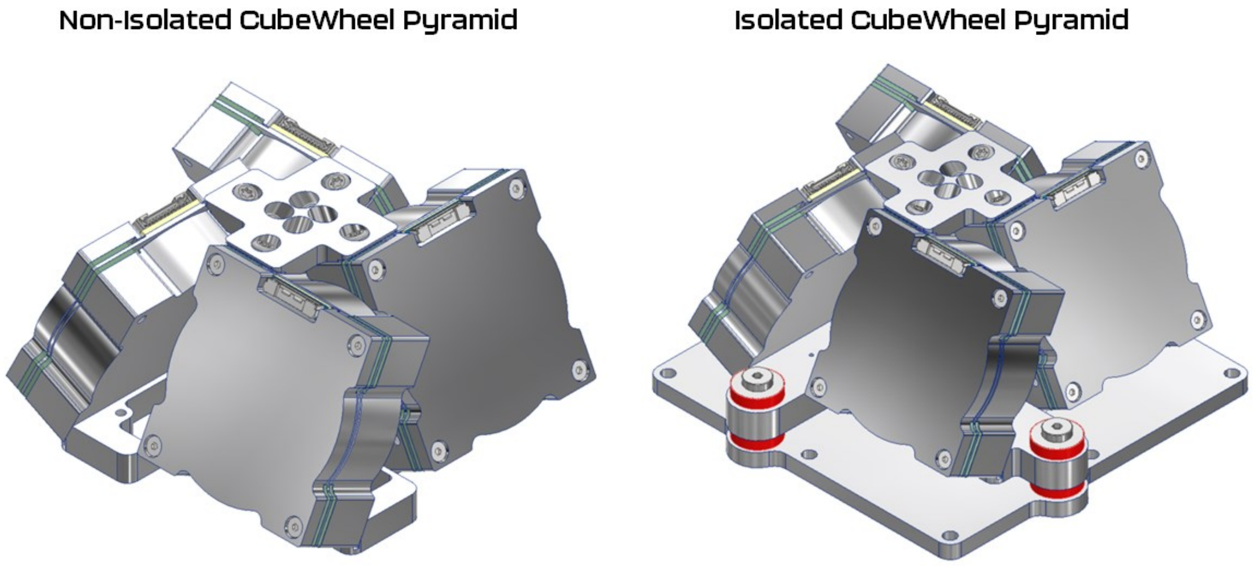

Figure 10: Example of Non-Isolated (left) and Isolated (right) CubeWheel Pyramid Configurations

4. Software Interface

Each CubeProduct is accompanied by a user manual [RD2] that provides detail regarding simple telemetry exchanges using ground support equipment. For further details regarding software interface and control, please refer to firmware reference manual [RD5].

5. EMI / EMC

5.1 Potential RF Emitter List

Table 20: Potential Emitters

Component	Frequency/Bit Rate	Frequency Stability
MCU	24 MHz	± 50 ppm
Comms UART	921600 Baud	± 50 ppm
Comms I2C	100 kHz	± 50 ppm
Comms CAN	1Mb/s	± 50 ppm
SPI	24 MHz	± 50 ppm
Motor driver PWM	6 kHz	± 50 ppm
Motor Driver oscillator 1	51.5 kHz	± 10 kHz
Motor Driver oscillator 2	103 kHz	± 21 kHz

5.2 EMI / EMC Cleanliness

5.2.1 Mounting Proximity Considerations regarding Magnetic Influence

CubeWheels have MuMetal to shield the rest of the satellite from the strong magnets inside the electrical motors of the wheel. This shielding significantly warps close proximity magnetic fields; therefore, it should not be mounted within 15cm of the magnetometer and 4cm of the magnetorquers.

Table 21 summarizes the magnetic influence of a rotating CubeWheel at a set distance, further information and illustrations can be found in the technical reference manual [RD3].

Table 21: CubeWheel Magnetic Influence

Model	Magnetic Influence [nT]	Distance from Sensor [cm]
CW0017	1550 ± 10%	5
CW0057	2100 ± 10%	5
CW0162	2100 ± 10%	5
CW0500	1600 ± 10%	10

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

5.2.2 Grounding

The enclosure and mechanical parts of CubeWheel are connected to the power and signal ground through a filter designed to minimise EMI, as illustrated in Figure 11. The enclosure of CubeWheel can be grounded by the user if desired.

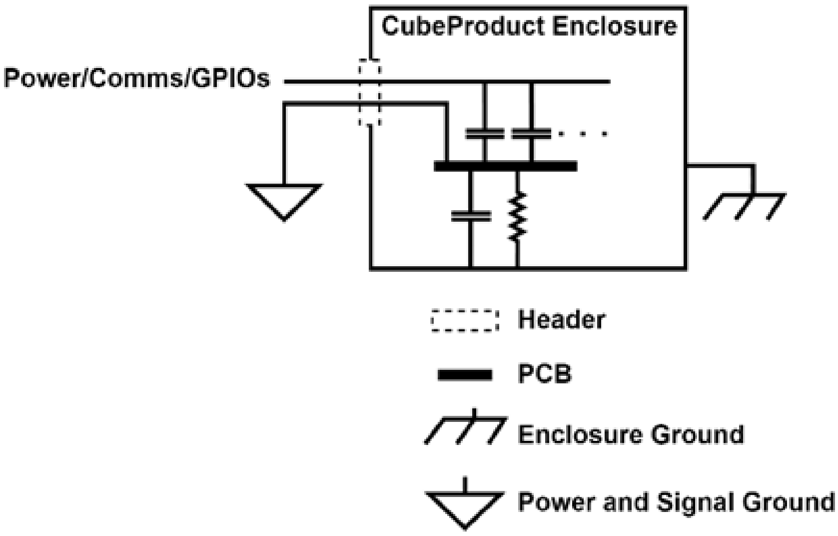

Figure 11: Generic Grounding Diagram

The enclosure's RC 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 away from the enclosure. The commonly used alternative method where the enclosures are directly connected to the ground introduces the risk that shorts could occur during satellite integration.

In some cases a customer might require the enclosure of CubeWheel to be completely isolated from the system ground by removing the EMI filters completely. In such a case, it should be specified as a custom option during order placement.

5.2.3 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 section 5.2.1.

5.2.4 Filtering and Suppression

5.2.4.1 Implementation on CubeWheel

The following noise filtering strategies are implemented on CubeWheel itself:

- All pins that are externally exposed through headers are filtered by way of 100pF decoupling to power and signal ground as shown in Figure 11: Generic Grounding .
- RC filtering is applied on the CAN, UART and I2C communication interfaces to minimize spurious frequencies above 1 MHz.

5.2.4.2 Considerations for ADCS / OBS

As part of a CubeADCS solution, the ADCS CubeComputer implements the following filtering to reduce any noise seen or introduced:

- LC filtering on the 3.3 V supply and the boot- and enable lines to CubeWheel
- Common-mode filtering on the CAN communication interface to CubeWheel
- Filtering on the satellite battery supply

For any standalone CubeWheel, similar filtering should be implemented on the client ADCS / OBC.