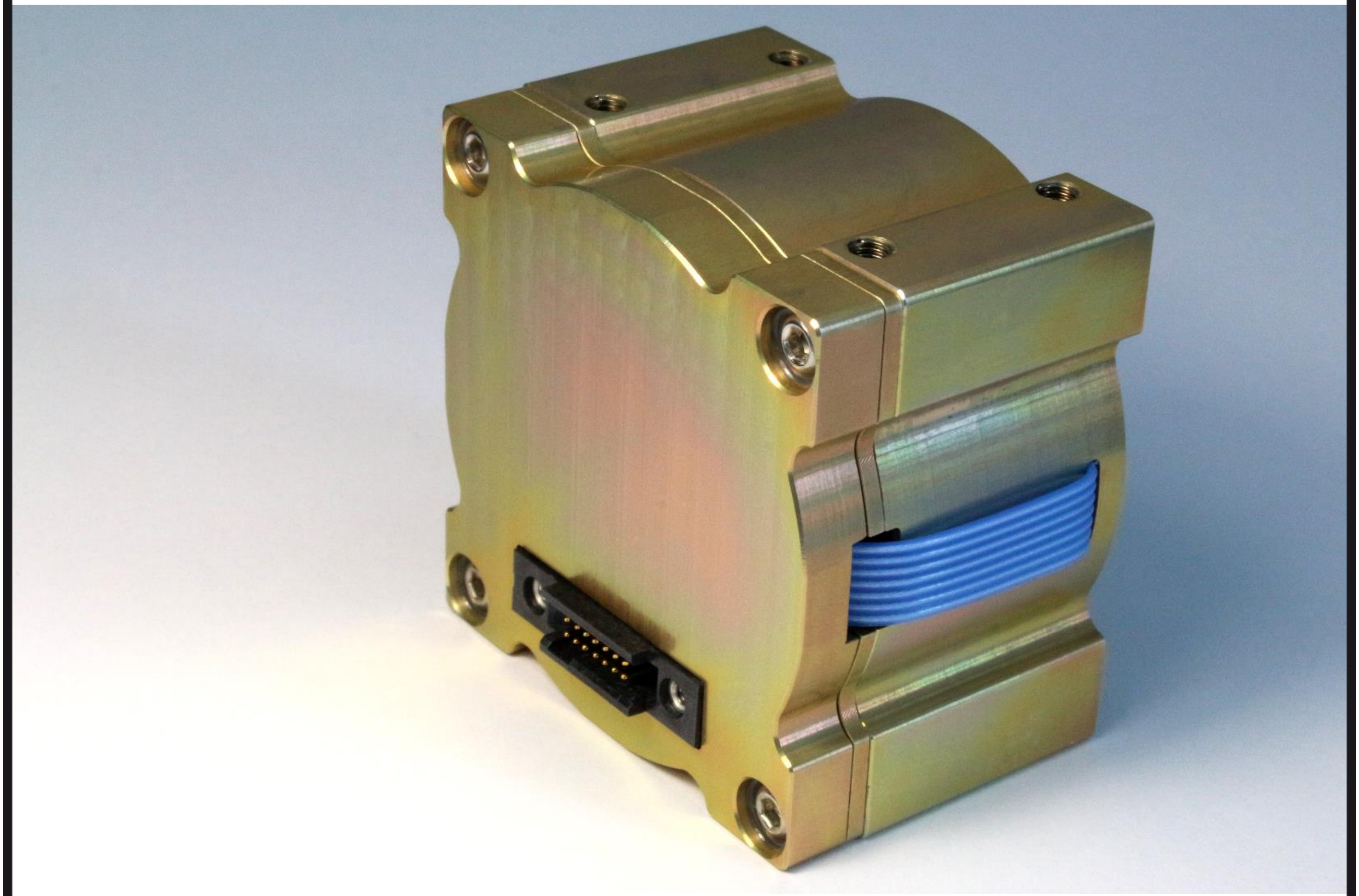
CubeWheel

Momentum/reaction wheels for nanosatellites



Interface Control Document

Contact Us

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

Physical Address

CubeSpace
The LaunchLab
Hammanshand Road
Stellenbosch, 7600
South Africa

Table of Contents

List of Acronyms/Abbreviations

ADCS	Attitude and Determination Control System
BLDC	Brushless DC
DC	Direct Current
ICD	Interface Control Document
I^2C	Inter-Integrated Circuit
MCU	Microcontroller Unit
OBC	On-Board Computer
RW	Reaction Wheel
TBC	To Be Confirmed
TBD	To Be Determined
TC	Telecommand
TLM	Telemetry
UART	Universal Asynchronous Receiver/Transmitter

1. Introduction

Momentum and reaction wheels are used to exchange angular momentum with a satellite body. This momentum exchange induces a control torque, which can be used to change the satellite's attitude or to absorb disturbances from the space environment (e.g. aerodynamic disturbance). Momentum/reaction wheels are commonly used in satellites that have moderate to high pointing accuracy requirements.

This document describes the interfaces to CubeWheel. A brief functional description of the unit is followed by the definition of the electrical, mechanical and software interfaces of the unit. This document is applicable to all sizes of CubeWheel units.

2. Functional Description

This section describes the hardware and software of CubeWheel.

2.1 Hardware

2.1.1 Mechanical assembly

The CubeWheel unit consists of a rotating flywheel attached to a brushless DC (BLDC) motor. A small PCB, which includes the necessary drive, control, and interface electronics, is attached to the bottom of the BLDC motor and is protected by an aluminium cover. The primary function of the electronics PCB is to measure and control the speed of the motor. The top cover of the CubeWheel unit supplies the necessary mounting holes for the user to mount the CubeWheel in any one of its 3 axes.

2.1.2 Size

CubeWheel is intended to be used in any satellite control system which is either momentum stabilised, or requires 3-axis reaction wheel control. The three sizes reaction wheels are shown in Figure 1

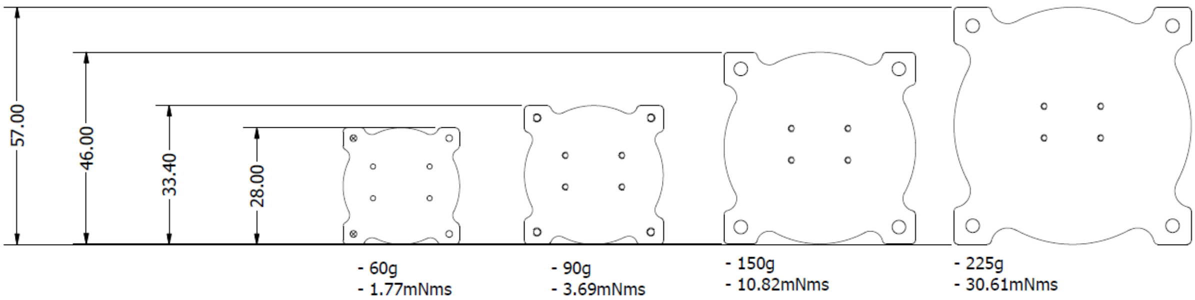


Figure 1: CubeWheel sizes

The size of the wheel typically scales with the size of the satellite. Table 1 shows a summary of the typical uses for the different sized wheels.

Table 1 – CubeWheel sizing guide

CubeWheel size	CubeSat size						
	2U	3U	4U	6U	8U	12U	Larger
Small and Small+	X	X	X				
Medium			X	X	X		
Large					X	X	X

2.1.3 Connector

Small and Small Plus CubeWheel units are supplied with a 14-way wire harness terminated in a female connector, whereas the Medium and Large units are supplied with a 14-way screw-down connector. More information regarding the harnesses and connectors of CubeWheel units can be found in Section 3.1 of this document.

2.1.4 Speed measurement

The speed of the motor is measured by two independent sources. The primary source of speed measurements is a magnetic encoder and the secondary source is the internal Hall sensors of the motor. Independent switches control the power to each one of these measurement sources. The speed control algorithms use the encoder measurements by default, but it can also use the Hall sensor measurements as a backup. Both measurements are available as telemetry (TLM).

2.1.5 Mounting

Various sets of mounting holes can be found on the cover of a CubeWheel unit, allowing the unit to be mounted in any of the 3 axes. The mechanical interface definition of the mounting holes can be found in Section 4 of this document.

2.1.6 Angular momentum

A positive rotation (resulting from a positive wheel speed reference or duty cycle command) can be translated to an angular momentum vector pointing out of the bottom of the CubeWheel unit. This is illustrated in Figure 2 and Figure 3.

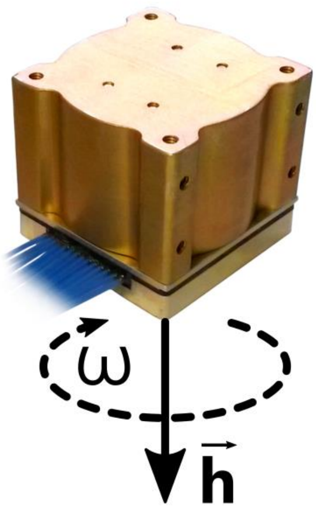


Figure 2 –Small and Small Plus angular momentum vector for a positive rotation

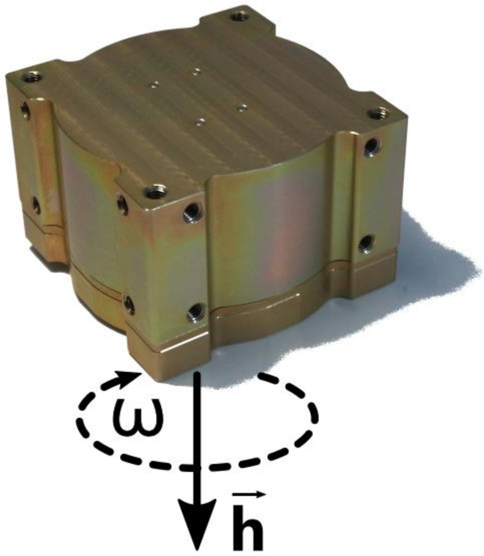


Figure 3 – Medium and Large angular momentum vector for a positive rotation

2.2 Software

The electronics PCB houses a microcontroller unit (MCU) that is responsible for commanding the motor driver, measuring the wheel's speed, performing speed control algorithms, measuring the motor's current, toggling power switches, and responding to telemetry requests and telecommands.

Two main aspects of the MCU's software are applicable to the user: the control state and backup mode.

2.2.1 Control state

The software on the MCU is governed by various control states. The MCU toggles power switches and commands the motor driver based on the current control state. There are four control states: **(1) *Idle*, (2) *No Control*, (3) *Duty Cycle*, and (4) *Speed Controller*.** The CubeWheel unit responds to telemetry requests and execute telecommands in any control state.

The ***Idle*** state is the initial start-up state, during which the unit has the lowest power consumption. The power switches to the motor and other non-critical components are switched off. Note that during this state, the motor current measurements are invalid.

During the ***No Control*** state, power to the motor is switched off, but sensor feedback (i.e. speed measurements) is still maintained. Note that during this state, the motor current measurements are invalid. The backup speed measurements are also invalid, because the motor is switched off.

A duty cycle command activates the ***Duty Cycle*** state. This state will maintain a reference control signal to the motor.

The speed of the wheel can actively be controlled (using either the primary or the secondary speed measurement as feedback) if the ***Speed Controller*** state is enabled. The speed reference can be set via telecommand (TC).

2.2.2 Backup mode

Redundancy is incorporated through the availability of two speed measurements (from the encoder, at 10 Hz, and from the Hall sensors, at 1 Hz). The speed control algorithm can use either the encoder, or the Hall sensors for feedback.

The user has the ability to enable or disable the so-called backup mode, which will switch off the encoder when activated via TC. Backup mode is disabled by default. **It should be noted that the default settling time of the backup mode speed controller is roughly ten times that of the encoder-based speed controller and will typically only be used for momentum wheel applications.**

2.2.3 Communication interfaces

All CubeWheel units can be configured to interface via I^2C, UART, or CAN. The specifications of each of these three interfaces can be found in Section 5 of this document. It should be noted that multiple communication interfaces can be used simultaneously.

Complete lists of telecommands telemetries can be found in Section 5.4 of this document.

3. Electrical Interface

3.1 Connector and harness

The CubeWheel unit has a single 14-way connection which contains all the required electrical connections to power and to communicate with the unit.

3.1.1 Configuration

The Small Plus wheel has a harness soldered in on the wheel side that terminates in a 14-way female Samtec SFSDT-series (screw down) connector. The Small wheel has an additional male Molex PicoBlade connector on the wheel itself and an accompanied harness which terminates with a female Samtec SFSDT-series (screw-down) connector. The Medium and Large CubeWheels are fitted with a male 14-way screw-down connector from the Samtec TFM-series, which mates with a Samtec SFSDT-series wired connector. Figure 4 illustrates the above-mentioned configurations of connectors and harnesses for use with CubeWheel units.

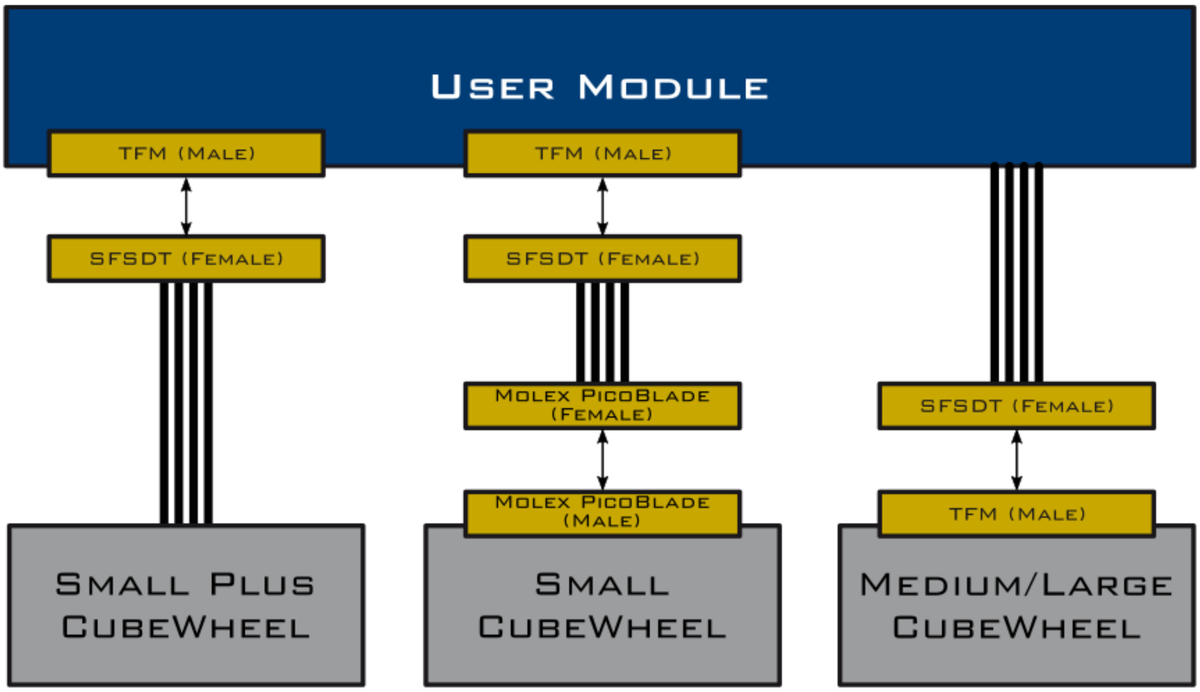


Figure 4 – CubeWheel connector and harness configurations

The Samtec parts used with CubeWheel units are the *SFSDT-07-30-G-XX.XX-SS* harness and the *TFM-107-02-L-D-DS*.

3.1.2 Pin definition

The pin definition of the 14-way connection is given by Table 2.

Table 2 – CubeWheel connector pin definition

Pin Number	Name	Description
1, 2	PGND	Power ground
3, 4	V_bat	Motor supply voltage
5	DGND	Digital ground
6	3V3	3.3 V supply for digital electronics
7	UART_TX	CubeWheel UART transmit (connect to Master_RX)
8	UART_RX	CubeWheel UART receive (connect to Master_TX)
9	Enable	Enable line (Active High)
10	I2C_SCL	I^2C clock line
11	I2C_SDA	I^2C data line
12	DGND	Digital ground
13	CANH	CAN high line
14	CANL	CAN low line

The location of pin 1 on the connector (and wire harness) is shown in Figure 5. Note that pin 1 is on the opposite corner of the polarity tab.

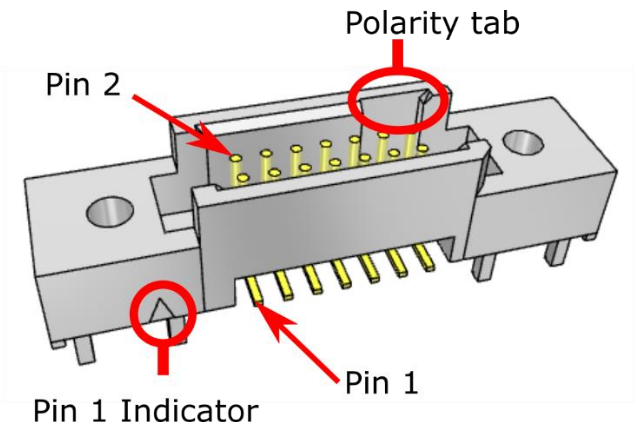


Figure 5 – Pin 1 on Samtec TFM-series connectors

The location of pin 1 on the PicoBlade header of a small wheel is shown in Figure 6.

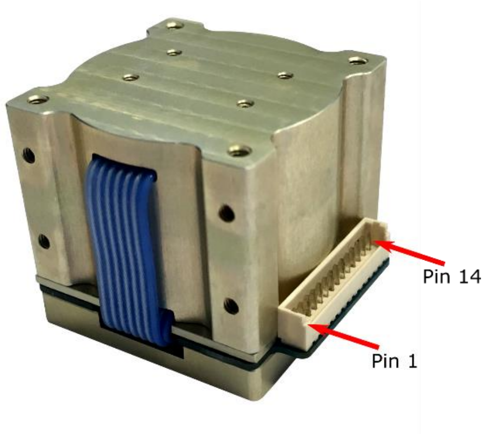


Figure 6 – Pin 1 on PicoBlade connectors

3.1.3 Physical properties

All the Samtec connectors have a current rating of at least 2.9 A and an operating temperature of -40°C to +125°C. The insulation of the SFSDT harnesses is made from Teflon. For further information regarding the connectors and harnesses, refer to www.samtec.com.

3.2 Power

A CubeWheel unit requires 3.3 V and the battery voltage, or $V_{battery}$, to operate. The digital electronics are powered by the 3.3 V line, whereas the motor runs off the battery voltage. The motor supply power is connected to a switch controlled by the MCU. The motor power switch is off by default and can be switched on via TC. The 3.3 V supplied to the CubeWheel unit directly powers the MCU, and a power switch on this line is controlled by the Enable pin.

The maximum and minimum of each voltage source are listed in Table 3.

Table 3 – Supply voltage maximum and minimum

Condition	3.3 V supply	$V_{battery}$ supply
Minimum	3.0 V	6.5 V
Nominal	3.3 V	8.0 V
Maximum	3.5 V	16.0 V

The power consumption of the CubeWheel units can be found in Section 7 of this document.

4. Mechanical Interface

This section shows the dimensions of the various sizes of CubeWheel units, as well as the mechanical definition of the mounting holes on the units.

4.1 Small CubeWheel

The Small CubeWheel unit has three sets of four M2 mounting holes on three different facets, as illustrated in Figure 7. The outer dimensions of the Small CubeWheel are 28 mm x 28 mm x 26.1 mm. Note that an additional 1.5 mm is required on one side of the CubeWheel for internal harnesses.

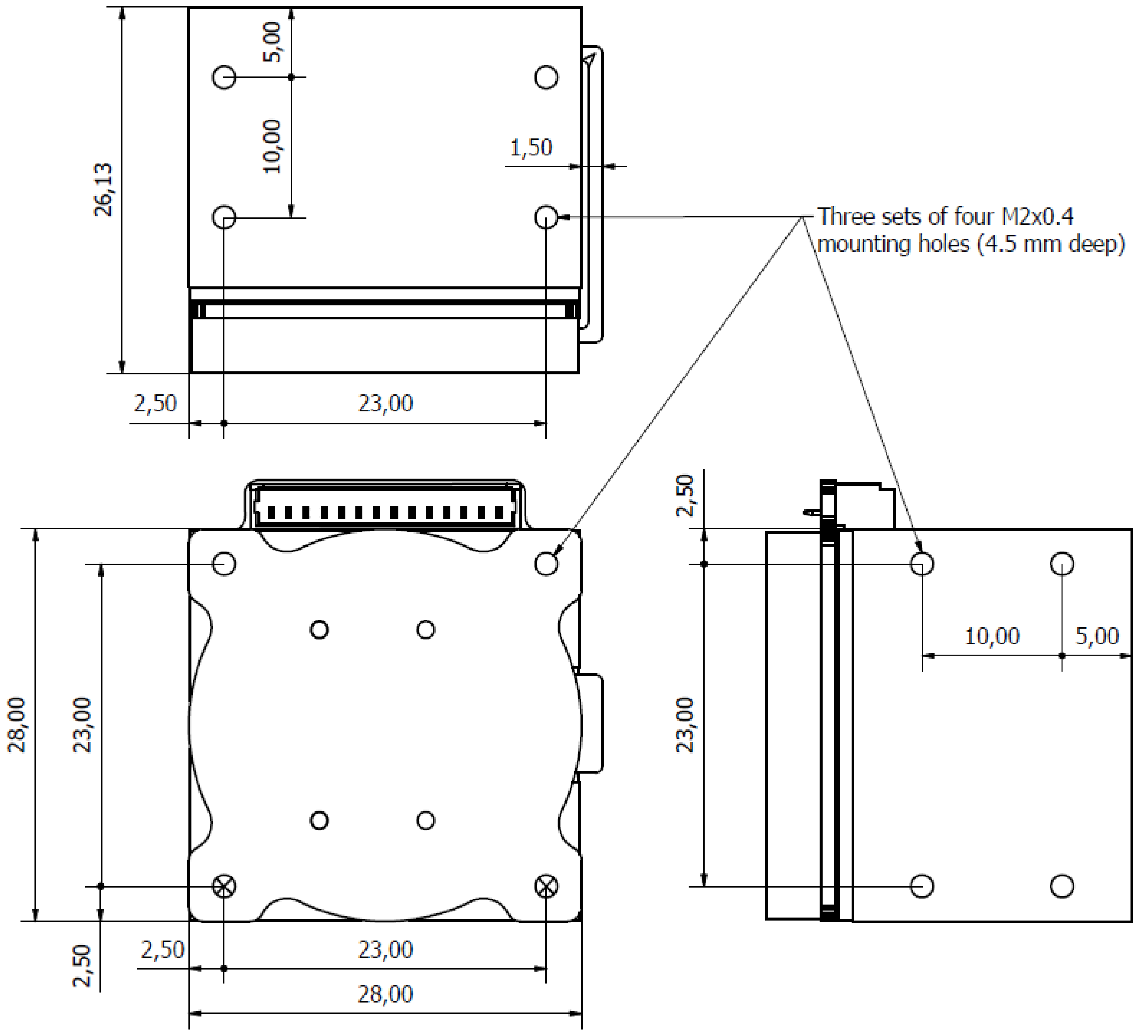


Figure 7 – Small CubeWheel mechanical interface

4.2 Small Plus CubeWheel

The Small Plus CubeWheel unit has three sets of four M2 mounting holes on three different facets, as illustrated in Figure 7. The outer dimensions of the Small Plus CubeWheel are 33.4 mm x 33.4 mm x 29.7 mm. Note that an additional 1.5 mm is required on one side of the CubeWheel for internal harnesses.

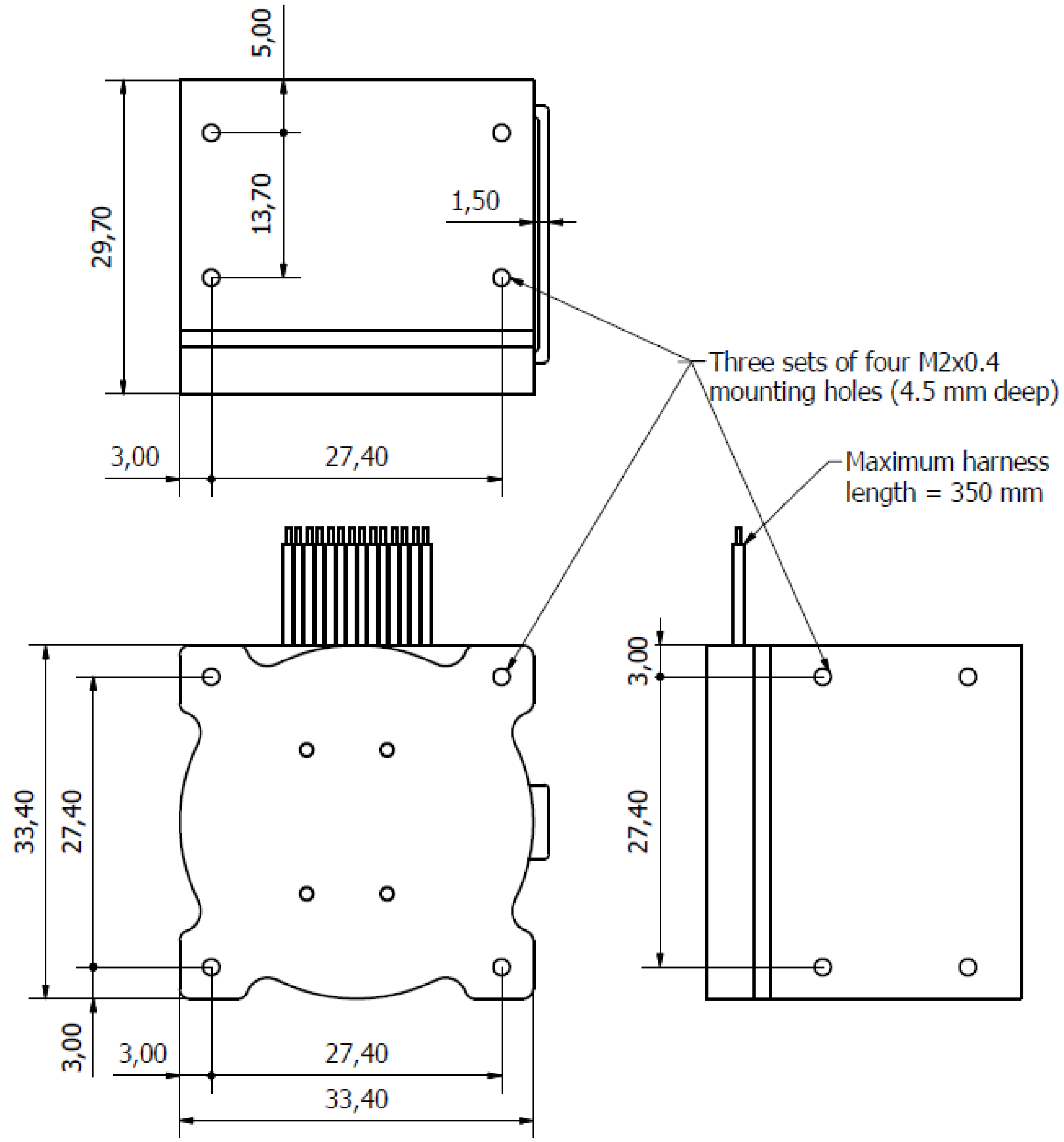


Figure 8 – Small Plus CubeWheel mechanical interface

4.3 Medium CubeWheel

The Medium CubeWheel unit has three sets of four M3 mounting holes on three different facets, as illustrated in Figure 9. The outer dimensions of the Medium CubeWheel are 46 mm x 46 mm x 31.5 mm. Note that an additional 1.5 mm is required on one side of the CubeWheel for internal harnesses. The M3 mounting holes will be fitted with A2 (304) stainless steel heli-coils to provide a stronger and more durable thread.

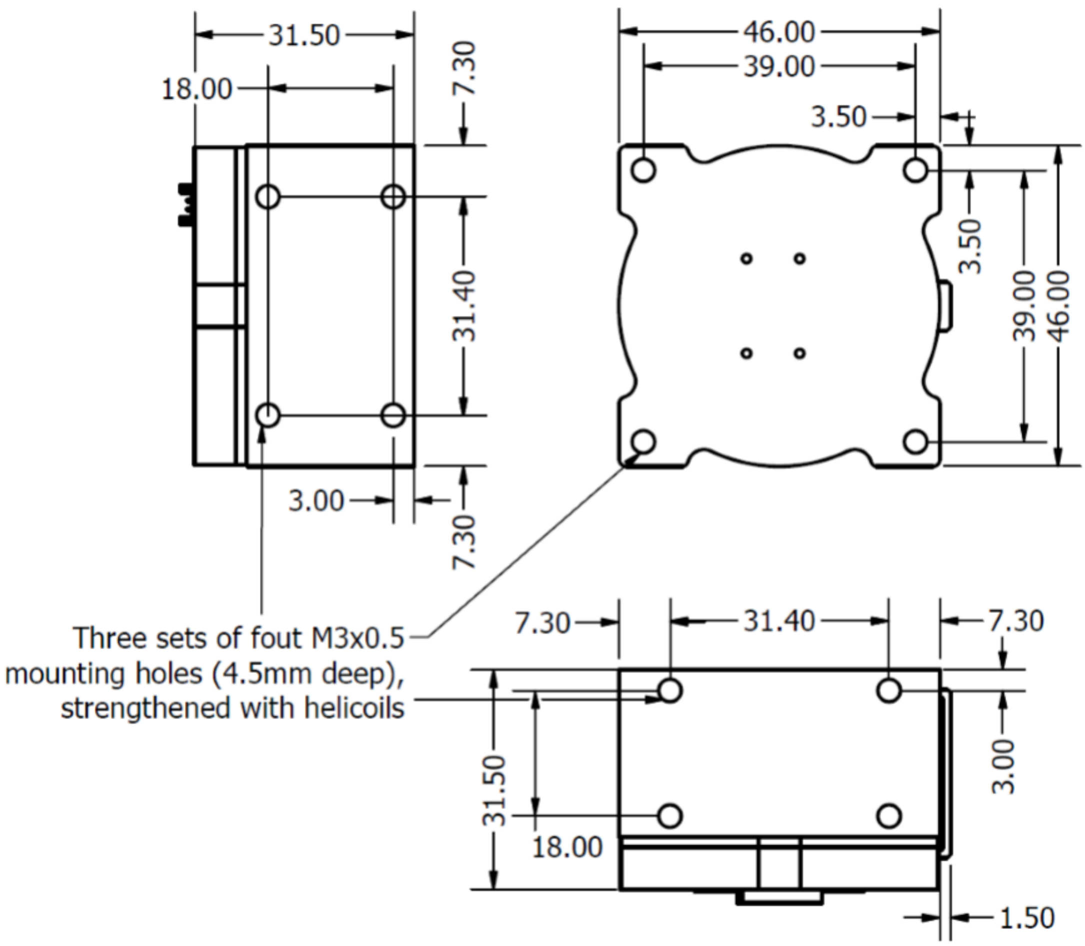


Figure 9 – Medium CubeWheel mechanical interface

4.4 Large CubeWheel

The Large CubeWheel unit has three sets of four M3 mounting holes on three different facets, as illustrated in Figure 10. The outer dimensions of the Large CubeWheel are 57 mm x 57 mm x 31.5 mm. Note that an additional 1.5 mm is required on one side of the CubeWheel for internal harnesses. The M3 mounting holes will be fitted with A2 (304) stainless steel heli-coils to provide a stronger and more durable thread.

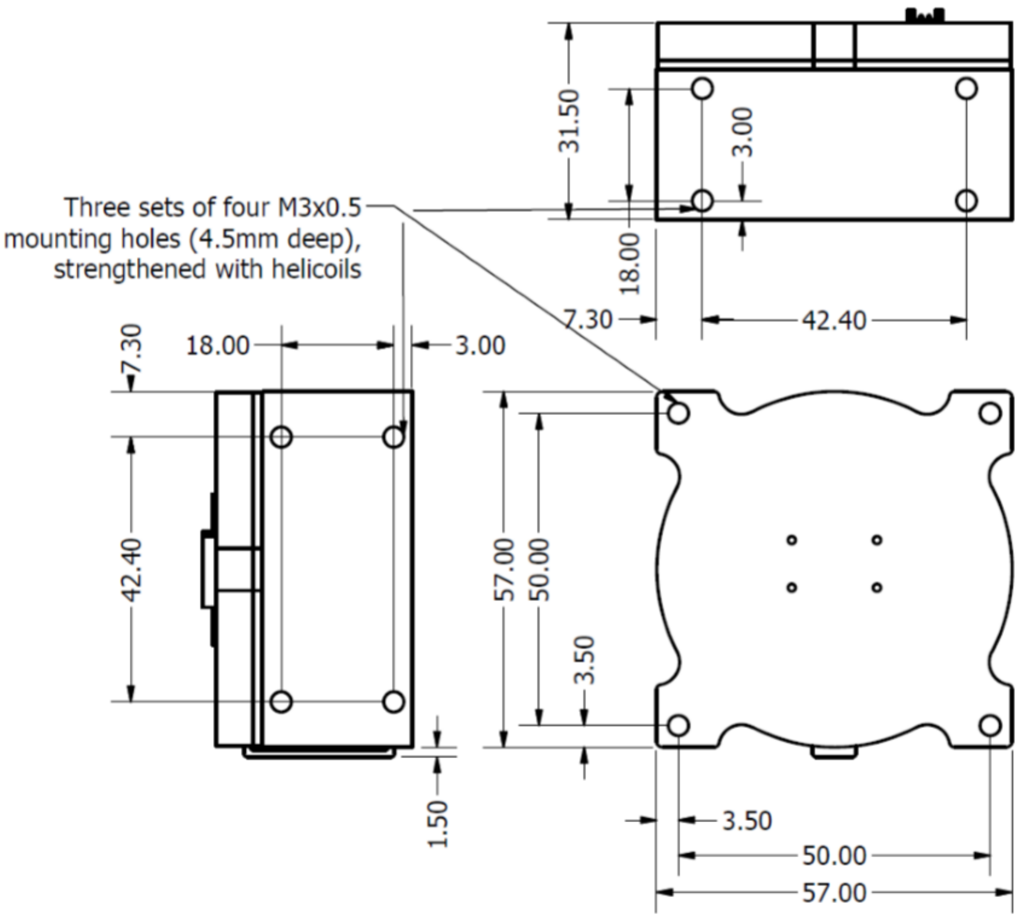


Figure 10 – Large CubeWheel mechanical interface

5. Software Interface

5.1 UART

The CubeWheel unit contains a UART buffer to isolate the unit. The logic of the unit operates at 3.3 V. **Using a higher voltage than 3.3 V may result in damage to the electronics.**

The specifications of the CubeWheel's UART interface are listed in Table 4.

Table 4 – UART specifications for CubeWheel units

Parameter	Value
Baud rate	115200
Data bits	8
Parity	None
Stop bits	1

The CubeWheel UART protocol includes two characters before and two characters after the TLM or TC packet. More information regarding the UART protocol can be found in the CubeWheel User Manual.

5.2 I^2C

The CubeWheel unit acts as an I^2C slave node with 7-bit addressing. The 8-bit read and write addresses of the unit are stored in the MCU's EEPROM and can be changed using the appropriate TC.

The CubeWheel unit contains an I^2C buffer to isolate the unit from the rest of the I^2C bus. Pull-up resistors are required on the data and clock lines between the unit and the master. The unit is set to work on 3.3 V I^2C logic.

Pull-up resistors on the I^2C bus need to be supplied by the master.

Information regarding the I^2C protocol can be found in the CubeWheel User Manual.

5.3 CAN (optional)

The CubeWheel unit acts as a slave on a 1 Mbps CAN V2.0B bus. The CAN mask (or address) of the unit is stored in the MCU's EEPROM and can be changed using the appropriate TC.

The CubeWheel unit contains a CAN transceiver module to isolate the unit from the rest of the CAN bus. The combination of the transceiver and an on-board CAN controller module allows the CubeWheel unit to interface with CAN bus voltage levels of 3.3 V or 5 V. There is no termination resistor populated between the CANH and CANL lines by default.

The CubeWheel unit does NOT have a termination resistor between the CANL and CANH lines. Clearly specify at time of placing order if termination resistor should be added.

Information regarding the CAN protocol can be found in the CubeWheel User Manual.

5.4 Telecommands and telemetries

The telecommands and telemetries available are listed in Table 5 and Table 6 respectively.

Table 5 – List of telecommands

ID	Name	Description	Length (bytes)
1	Reset	Perform a microcontroller reset	1
2	Wheel Reference Speed	Set momentum wheel reference speed	2
3	Wheel Commanded Torque	Set momentum wheel commanded torque	2
7	Motor Power State	Turn motor power on/off	1
8	Encoder Power State	Turn encoder power on/off	1
9	Hall Power State	Turn Hall sensors power on/off	1
10	Control Mode	Set the motor control mode	1
12	Backup Wheel Mode	Set the back-up wheel mode	1
20	Clear Errors	Clear the processor error flags	1
31	Set I^2C Address	Set I^2C address	1
32	Set CAN Mask	Set CAN mask	1
33	Set PWM Gain	Set general PWM proportional gain	3
34	Set Main Gain	Set gain of main speed controller	6
35	Set Backup Gain	Set gain of backup speed controller	6

Table 6 – List of telemetries

ID	Name	Description	Length (bytes)
128	Identification	Identification information for this node	8
129	Extended Identification	Extended Identification information on this node	4
130	Wheel Status	Current status telemetry of wheel electronics	8
133	Wheel Speed	Wheel speed measurement	2
134	Wheel Reference	Wheel reference speed	2
135	Wheel Current	Wheel current measurement	2
137	Wheel Data	Complete wheel data	6
138	Wheel Data Additional	Additional wheel data	4
139	PWM Gain	General PWM gain	3
140	Main Gain	Main speed controller gain values	6
141	Backup Gain	Backup speed controller gain values	6
145	Status and Error Flags	Processor status and error flags	1

6. Hardware manufacturing

The mechanical parts of CubeWheels are manufactured by a local company that has **AS9100 AeroSpace Manufacturing certification**. All housing parts are CNC milled, and the flywheels are CNC lathed. Thereafter, Aluminium parts are given a Chromate conversion coating using Alucoat 650.

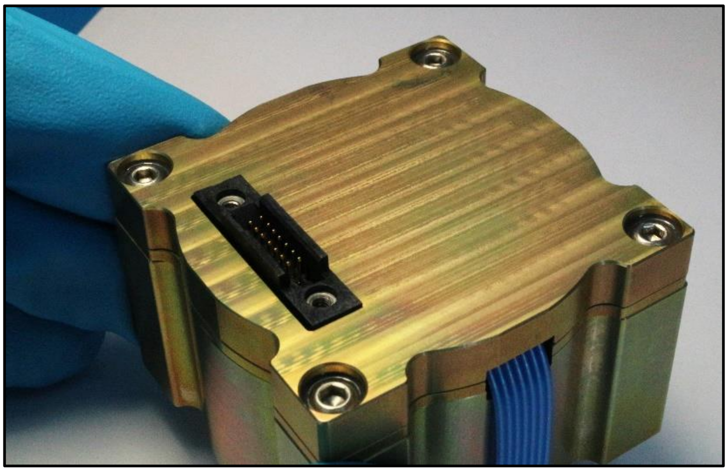


Figure 11: Aluminium CNC part with Alucoat finish

6.1 Momentum disc mounting and balancing

There are two main components to ensuring good balance of the flywheels that are used in the production of CubeWheels. Firstly, the flywheels are machined from high quality brass to a very low tolerance of ±0.01mm and ±0.005mm on certain critical dimensions.

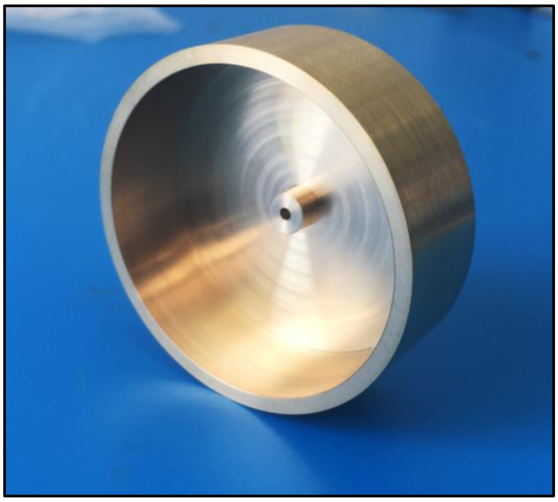


Figure 12: Precision manufactured brass flywheel

Thereafter the flywheel is integrated onto an electrical motor, and mounted on an Aluminium base. Once assembled, the wheel is mounted on our balance measurement equipment, and spun up to various speeds. The imbalance is then determined, and the position of the imbalance is identified. The assembled wheel is then mounted on a jig that supports the flywheel, protects the rest of the mechanical parts, and seals the electrical motor and bearings from dust. It is then mounted in a milling machine, and a small amount of brass is removed by manual operation of the machine.

Figure 13: Post manufacturing balanced brass flywheel

All wheels are balanced to the following spec:

	Small	**Small Plus**	**Medium**	**Large**
Static imbalance	<0.003 g.cm	<0.004 g.cm	<0.004 g.cm	<0.006 g.cm
Dynamic imbalance	<0.005 g.cm^2	<0.014 g.cm^2	<0.014 g.cm^2	<0.05 g.cm^2

7. Specifications

Table 7: CubeWheel Small Specifications

<table>
<tr><th colspan="7">Supply voltage</th></tr>
<tr><td colspan="4" rowspan="2">Digital supply voltage (3V3)</td><td>Min</td><td>Nom</td><td>Max</td></tr>
<tr><td>3.0V</td><td>3.3V</td><td>3.5V</td></tr>
<tr><td colspan="4" rowspan="2">Power supply voltage (Battery)</td><td>Min</td><td>Nom</td><td>Max</td></tr>
<tr><td>6.5V</td><td>N/A</td><td>16V</td></tr>
<tr><th colspan="7">Supply power usage</th></tr>
<tr><td colspan="4">500 rpm</td><td colspan="3">105mW</td></tr>
<tr><td colspan="4">2000 rpm</td><td colspan="3">125mW</td></tr>
<tr><td colspan="4">6000 rpm</td><td colspan="3">177mW</td></tr>
<tr><th colspan="7">Momentum and speed</th></tr>
<tr><td colspan="4">Maximum momentum storage</td><td colspan="3">1.7 mNms</td></tr>
<tr><td colspan="4">Maximum wheel speed</td><td colspan="3">± 8000 rpm</td></tr>
<tr><td colspan="4">Maximum torque</td><td colspan="3">0.23 mNm</td></tr>
<tr><td>Speed Control</td><td>50rpm</td><td>500rpm</td><td>2000rpm</td><td colspan="3">6000rpm</td></tr>
<tr><td>Δ Speed(3σ)</td><td>±5rpm</td><td>±2.5rpm</td><td>±3rpm</td><td colspan="3">±3rpm</td></tr>
<tr><td>Δ Speed(3σ) (Backup Mode)</td><td>-</td><td>±10rpm</td><td>±50rpm</td><td colspan="3">±50rpm</td></tr>
</table>

Table 8: CubeWheel Small Plus Specifications

<table>
<tr><th colspan="7">Supply voltage</th></tr>
<tr><td colspan="4" rowspan="2">Digital supply voltage (3V3)</td><td>Min</td><td>Nom</td><td>Max</td></tr>
<tr><td>3.0V</td><td>3.3V</td><td>3.5V</td></tr>
<tr><td colspan="4" rowspan="2">Power supply voltage (Battery)</td><td>Min</td><td>Nom</td><td>Max</td></tr>
<tr><td>6.5V</td><td>N/A</td><td>16V</td></tr>
<tr><th colspan="7">Supply power usage</th></tr>
<tr><td colspan="4">500 rpm</td><td colspan="3">110mW</td></tr>
<tr><td colspan="4">2000 rpm</td><td colspan="3">140mW</td></tr>
<tr><td colspan="4">6000 rpm</td><td colspan="3">250mW</td></tr>
<tr><th colspan="7">Momentum and speed</th></tr>
<tr><td colspan="4">Maximum momentum storage</td><td colspan="3">3.6 mNms</td></tr>
<tr><td colspan="4">Maximum wheel speed</td><td colspan="3">± 6000 rpm</td></tr>
<tr><td colspan="4">Maximum torque</td><td colspan="3">2.3 mNm</td></tr>
<tr><td>Speed Control</td><td>50rpm</td><td>500rpm</td><td>2000rpm</td><td colspan="3">6000rpm</td></tr>
<tr><td>Δ Speed(3σ)</td><td>±5rpm</td><td>±2.5rpm</td><td>±3rpm</td><td colspan="3">±3rpm</td></tr>
<tr><td>Δ Speed(3σ) (Backup Mode)</td><td>-</td><td>±10rpm</td><td>±50rpm</td><td colspan="3">±50rpm</td></tr>
</table>

Table 9: CubeWheel Medium Specifications

<table>
<tr><th colspan="7">Supply voltage</th></tr>
<tr><td colspan="4" rowspan="2">Digital supply voltage (3V3)</td><td>Min</td><td>Nom</td><td>Max</td></tr>
<tr><td>3.0V</td><td>3.3V</td><td>3.5V</td></tr>
<tr><td colspan="4" rowspan="2">Power supply voltage (Battery)</td><td>Min</td><td>Nom</td><td>Max</td></tr>
<tr><td>6.5V</td><td>N/A</td><td>16V</td></tr>
<tr><th colspan="7">Supply power usage</th></tr>
<tr><td colspan="4">500 rpm</td><td colspan="3">150mW</td></tr>
<tr><td colspan="4">2000 rpm</td><td colspan="3">185mW</td></tr>
<tr><td colspan="4">6000 rpm</td><td colspan="3">390mW</td></tr>
<tr><th colspan="7">Momentum and speed</th></tr>
<tr><td colspan="4">Maximum momentum storage</td><td colspan="3">10.8 mNms</td></tr>
<tr><td colspan="4">Maximum wheel speed</td><td colspan="3">± 6000 rpm</td></tr>
<tr><td colspan="4">Maximum torque</td><td colspan="3">1.0 mNm</td></tr>
<tr><td>Speed</td><td>50rpm</td><td>500rpm</td><td>2000rpm</td><td colspan="3">6000rpm</td></tr>
<tr><td>Δ Speed(3σ)</td><td>±2rpm</td><td>±1.5rpm</td><td>±1rpm</td><td colspan="3">±0.5rpm</td></tr>
<tr><td>Δ Speed(3σ) (Backup Mode)</td><td>-</td><td>±10rpm</td><td>±30rpm</td><td colspan="3">±30rpm</td></tr>
</table>

Table 10: CubeWheel Large Specifications

<table>
<tr><th colspan="7">Supply voltage</th></tr>
<tr><td colspan="4" rowspan="2">Digital supply voltage (3V3)</td><td>Min</td><td>Nom</td><td>Max</td></tr>
<tr><td>3.0V</td><td>3.3V</td><td>3.5V</td></tr>
<tr><td colspan="4" rowspan="2">Power supply voltage (Battery)</td><td>Min</td><td>Nom</td><td>Max</td></tr>
<tr><td>6.5V</td><td>N/A</td><td>16V</td></tr>
<tr><th colspan="7">Supply power usage</th></tr>
<tr><td colspan="4">500 rpm</td><td colspan="3">175mW</td></tr>
<tr><td colspan="4">2000 rpm</td><td colspan="3">350mW</td></tr>
<tr><td colspan="4">6000 rpm</td><td colspan="3">790mW</td></tr>
<tr><th colspan="7">Momentum and speed</th></tr>
<tr><td colspan="4">Maximum momentum storage</td><td colspan="3">30.6 mNms</td></tr>
<tr><td colspan="4">Maximum wheel speed</td><td colspan="3">± 6000 rpm</td></tr>
<tr><td colspan="4">Maximum torque</td><td colspan="3">2.3 mNm</td></tr>
<tr><td>Speed</td><td>50rpm</td><td>500rpm</td><td>2000rpm</td><td colspan="3">6000rpm</td></tr>
<tr><td>Δ Speed(3σ)</td><td>±2rpm</td><td>±1rpm</td><td>±1rpm</td><td colspan="3">±2rpm</td></tr>
<tr><td>Δ Speed(3σ) (Backup Mode)</td><td>-</td><td>±30rpm</td><td>±20rpm</td><td colspan="3">±15rpm</td></tr>
</table>

Table 11: Environment testing specifications

Vibration	**Level**		**Notes**
Sine	2.5g		
Random	**Freq**	**Amp**	8.03g RMS
	20	0.01125	
	130	0.05625	
	800	0.05625	
	2000	0.015	
Thermal vacuum	**Level**		**Notes**
Pressure	0.8mBar		
Temperature range (test)	-5C to 60C Cycling		Electrical component theoretical specifications: -25 to 80C
Radiation	**Level**		**Notes**
Total dose	20kRad		3 units direct exposure to Cobalt 60 source without failure or noticeable degrade
Dose rate	4kRad/h		

8. Document Version History

Version	Author(s)	Pages	Date	Description of change
0.1	HWJ	ALL	04/12/2015	First draft
1.0	HWJ	ALL	08/12/2015	Added Medium and Large Wheel info
1.1	GJVV	ALL	18/03/2016	Several major updates
1.2	GJVV	16	26/05/2016	Updated masses
1.3	GJVV	10	15/06/2016	Added heli-coil information
1.4	GJVV	ALL	29/07/2016	Updated template Updated CAD of mechanical interface
1.5	GJVV	11, 17	18/08/2016	Corrected drawing of Small CubeWheel Updated masses based on accurate CADs Updated Small CubeWheel dimensions Updated Small CubeWheel power
1.6	MK	11, 12, 13, 17	05/02/2017	Removed helicoils on small wheel Updated Medium drawings Updated Large drawings Update M&L MoI Updated Medium wheel specs
1.7	MK	All	06/03/2017	Update Specifications, formatting
1.8	DGS	9, 10	15/05/2017	Update for v1.3 PCB. Enable pin added
1.9	MK	All	27/06/2017	Imbalance spec; General grammar
1.10	DGS	7,15	12/07/2017	Fixed RESET and explained currents measured during Idle and No-control modes
1.11	DGS	8	17/10/2017	Changed cabling description for small CubeWheel
1.12	DGS	20	25/10/2017	New power specs for vacuum bearing
1.13	DGS	10	14/8/2018	Changed pinout descriptions
1.14	DGS	All	18/07/2019	Added Small Plus descriptions
1.15	DGS	21, 22	18/09/2019	Changed specifications table