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EXOpod
User Manual

Cubesat deployment system
Revision 6.0 | September 2022

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Change Log

Version	Author	Date	Changes
1.0	SP	23 Jun 2016	First release
2.0	SP	15 Mar 2018	EXObox information added. Feature description extended
3.0	MT	20 Jan 2019	Transition to Exolaunch style. Various small updates, updated cubesat interfaces in section 2.3, added thermal interfaces in chapter 6.
4.4	MT	30 Apr 2021	- Added information about qualification status in section 1.4 - Updated flight heritage, updated tuna can parameters in section 2.3 - Added Cubesat COG offset information in section 2.3 - Updated deployment parameters in section 2.4 - Updated details of mechanical interface in section 4.1 - Updated clamping forces in section 4.2.1 - Extended description of clamping mechanism in section 4.2.1 - Added EXOpod slot number allocation in section 5.2 - Updated electrical characteristics in section 5.2
5.0	MT	01 Dec 2021	- Updated overall design - Updated available tuna can diameters in Table 11 - Updated connector pinout/slot numbers in section 5.2 and Appendix 8D
6.0	MT	06 Sep 2022	- Updated overall layout. - Updated description of EXOpod configurations in section 2.2. - Added description and figures for the cubesat allowable volume in section 2.3. - Updated allowable cubesat Z-axis tolerance in Table 1. - Added equation for cubesat separation time calculations in section 2.4. - Added POI values to mass properties in section 3.2. Moved detailed mass properties to Appendix A. - Updated lifting interface description in section 4.1.4. - Updated clamping system description and clamping forces in section 4.2.1. - Updated thermal interfaces description in chapter 6. - Added chapter 7 "Integration and Transportation.

Applicable Documentation

#	Changes
AD-1	CubeSat Design Specification Rev. 13
AD-2	EXOpod Cubesat Integration Guide

Acronyms

Acronym	Description
BPM	Bottom Plate Mounting
CDS	CubeSat Design Specification Standard Rev. 13
COG	Center of Gravity
COTS	Commercial Off the Shelf
ISO	International Organization for Standardization
MOI	Moment of Inertia
PEEK	Polyetheretherketone, ketone based semi-crystalline thermoplastic
POI	Product of Inertia
RBF	Remove Before Flight
RPM	Rear Plate Mounting
US	Upper Stage

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Introduction

1.1 EXOpod Cubesat Deployers

Cubesats have been extremely successful in facilitating access to space. Since the California Polytechnic State University (Cal Poly) and Stanford University developed and introduced the cubesat Design Specification in 1999, hundreds of cubesats have been launched. Due to their small size and low mass, as well as the use of standardized separation systems, cubesats are compatible with a multitude of launchers which makes them ideal for launch as rideshare payloads. Containerized separation systems also minimize risks to both the primary payload and the launch vehicle.

Exolaunch has developed its EXOpod cubesat Deployers in this context. They are the most advanced separation systems on the market, offering a combination of the highest reliability and user-friendliness, as well as multiple features that expand the limits of the cubesat Design Specification. The EXOpod Deployer has one of longest flight histories of any system on the market having flown of 13 missions since 2017.

EXOpods are designed to ensure easy integration, safe transportation, and reliable separation of cubesats. In its basic configuration, the 12U EXOpod can feature up to four separation slots, each capable of holding a 3U cubesat or smaller. Special adapters can also be implemented used to load 1U and 2U cubesats into 3U slots. Furthermore, individual slots can be connected, allowing a 12U EXOpod to carry two 6U or one 12U cubesat. The 16U version of the EXOpod can be configured to accommodate two 6U XL, two 8U, or one 16U cubesats.

Figure 1: EXOpod 3U cubesat integration

1.2 Purpose and Applicability

This User Manual defines the interface requirements between EXOpod and cubesats for developers using Exolaunch launch services and products, as well as for launch providers. EXOpod is designed as a standardized deployment system to launch and deploy any satellite that complies with the **CubeSat Design Specification Rev. 13**. EXOpod also allows for the deployment of cubesats that exceed the limits of the cubesat Design Specification in several key domains, which this User Manual in turn defines. The document also specifies the minimum requirements for compatibility with EXOpod and the Launch Vehicle flight safety program when using Exolaunch services. This includes a description of all mechanical, thermal, and electrical interfaces, as well as their performance specifications.

This document is valid until it is rescinded by Exolaunch or is superseded by a subsequent document version.

1.3 Quality Assurance

Quality assurance for the EXOpod deployment system is ensured at every step of the production chain. The entire production line fulfils the highest quality assurance requirements. Additionally, the facilities that manufacture Exolaunch products are certified with ISO 9001:2015 standards, which require regular inspection of the manufacturing and assembly facilities, while ensuring consistent quality of the final product. These same quality standards are applied to the qualification and acceptance testing processes.

1.4 Qualification and Flight Heritage

The EXOpod deployer family has flight heritage since 2017. It has been launched on over a dozen missions and has **successfully deployed more than 172 cubesats** between 0.25U and 16U into orbit without failure.

The universal compatibility with any launch vehicle on the market has been a key design driver underpinning EXOpod. To date, EXOpod has been consistently environmentally qualified for all of Exolaunch's launch providers.

The rigorous nature of the qualification testing performed by Exolaunch, means that EXOpod meets or exceeds the requirements of a majority of launch vehicles on the market. The list of qualifications is constantly growing in line with market demand and the addition of new launch vehicles to our portfolio.

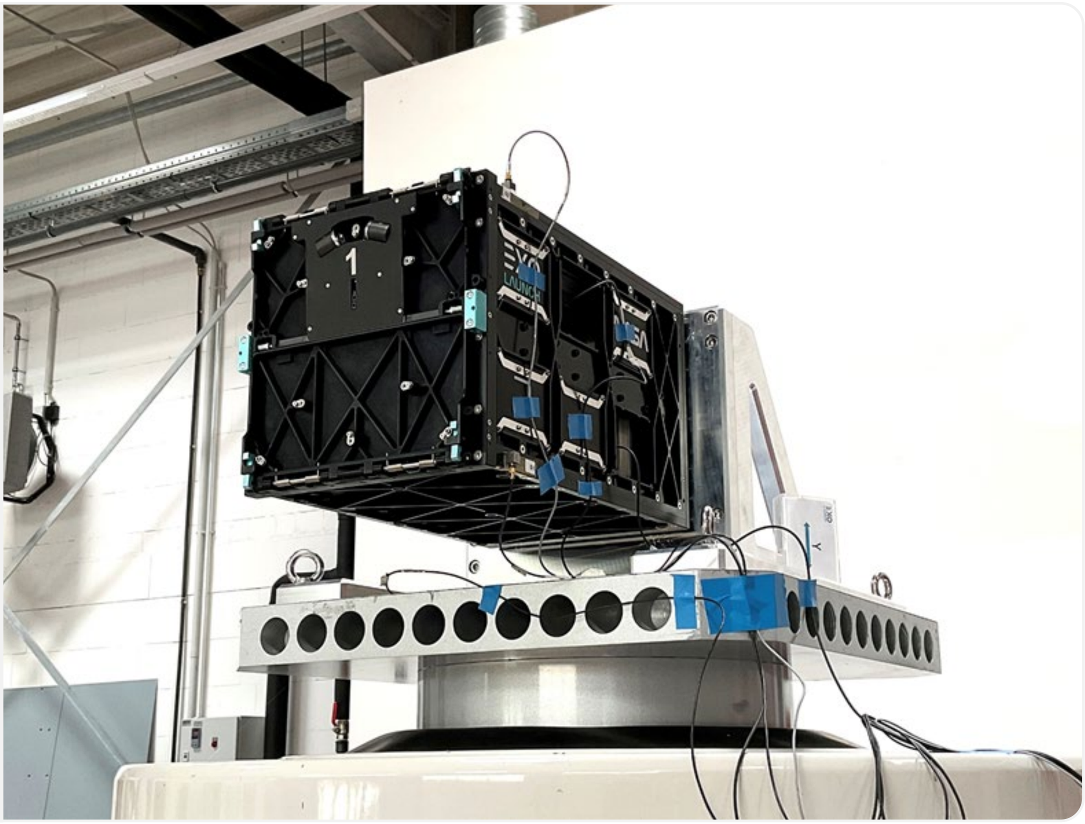


Figure 2: EXOpod during environmental qualification testing

2

EXOpod Cubesat Deployer

2.1 Components and Features

The chassis of the EXOpod is stiff enough to not depend on the integration of cubesats to provide structural support and can launch with an empty slot without complications. The main components of both 12U and 16U EXOpods are shown below in Figure 3. Each component is described in further detail in subsequent sections.

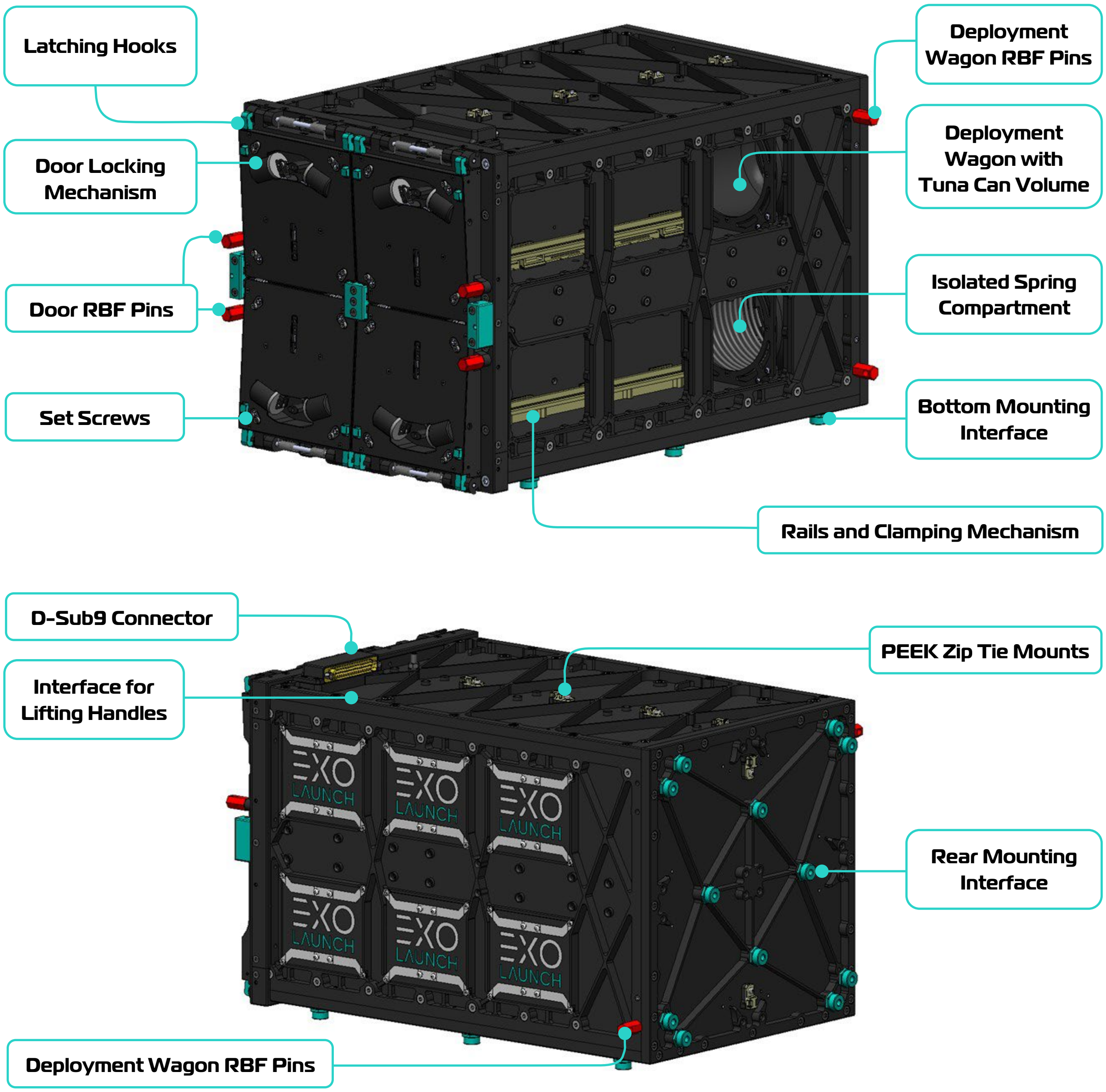


Figure 3:
Overview of the EXOpod's main components, closed and with the deployment wagon and spring secured in the rear of the deployer

2.2 EXOpod Configurations

The EXOpod configurations are assigned with S-codes according to the number of slots. Each slot is separated by a divider-plate to avoid interference. The figures in the subsequent sections illustrate all possible internal configurations for both 12U and 16U EXOpod variations (Figure 4 to Figure 7 for the 12U, and Figure 8 to Figure 9 for the 16U).

Slots can also be adapted to carry smaller cubesats using special adapters. A 3U slot can be used to launch 1U or 2U cubesats, while an 8U slot in the 16U EXOpod can be adapted to accommodate a 6U XL cubesat.

2.2.1 12U EXOpod Configurations

12U S1 — 1x12U Slot

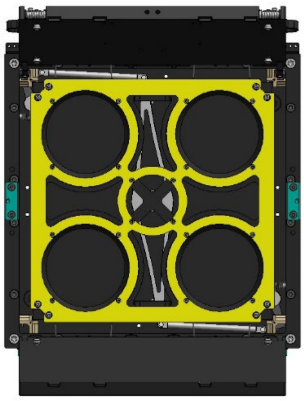


Figure 4: Left: Representation of 12U S1 EXOpod in both closed (Top) and open (Bottom) states. Right: internal layout

12U S2 — 2x6U Slot

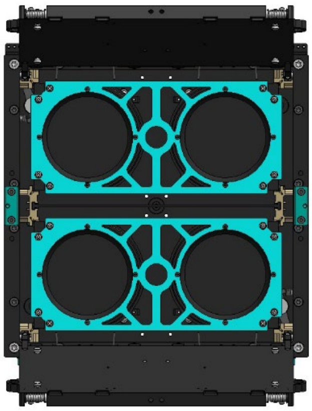


Figure 5: Left: Representation of 12U S2 EXOpod in both closed (Top) and open (Bottom) states. Right: internal layout

12U S3 — 2x3U Slot and 1x6U Slot

Figure 6: Left: Representation of 12U S3 EXOpod in both closed (Top) and open (Bottom) states. Right: internal layout

12U S4 — 4x3U Slots

Figure 7: Left: Representation of 12U S4 EXOpod in both closed (Top) and open (Bottom) states. Right: internal layout

2.2.2 16U EXOpod Configurations

16U S1 – 1x16U Slot

Figure 8: Left: Representation of 16U S1 EXOpod in both closed (Top) and open (Bottom) states. Right: internal layout

16U S2 – 2x6UXL or 2x8U Slot

Figure 9: Left: Representation of 16U S2 EXOpod in both closed (Top) and open (Bottom) states. Right: internal layout

2.3 Cubesat Allowable Volume

The general requirements of cubesats are provided in the cubesat Design Specification (CDS) Standard Rev. 13. In the past, cubesat deployers have been developed to follow the CDS. However, EXOpod has been designed to allow cubesats to exceed certain limitations of the cubesat Design Specification in terms of allowable mass and volume. Importantly, EXOpod is also backwards-compatible, and therefore is still able to accommodate any fully CDS-compliant cubesat even if it does not take advantage of EXOpod's enhanced performance envelope.

EXOpod can accommodate cubesats of 1U to 16U as standard. Specific demands for non-standard (for example 0.25U volume cubesats) may also be discussed with Exolaunch.

The maximum dimensions for 1U to 16U cubesats that may be used with EXOpod are provided in Table 1, and are further illustrated in Figure 10 and Figure 11. Here, the red areas mark the rails – the primary interfaces with EXOpod. The **GREY** and **BLUE** (the so-called "Tuna Can") volumes may be used by the customer. The rails comply with the CDS and have a tolerance of ±0.1 mm, which must be adhered to if the cubesat is to fit within the deployer. There is no strict tolerance for all other dimensions. Protruding features may be of any size within the usable volume envelope, but no part may extend beyond it.

The CDS states that Aluminum 7075, 6061, 5005, and/or 5052 may be used for both the main cubesat structure and the rails.

Caution: **The rails must additionally be hard anodized (Type III hard anodization).** Any deviation from the CDS, such as, but not limited to, the use of a different material or surface finishes (e.g. other forms of anodizing or a chromate conversion dual finish) must be approved by Exolaunch in written form. Furthermore, any holes or edges on the cubesat rail must be adequately chamfered. The rails must have a surface roughness of Ra ≤ 1.6.

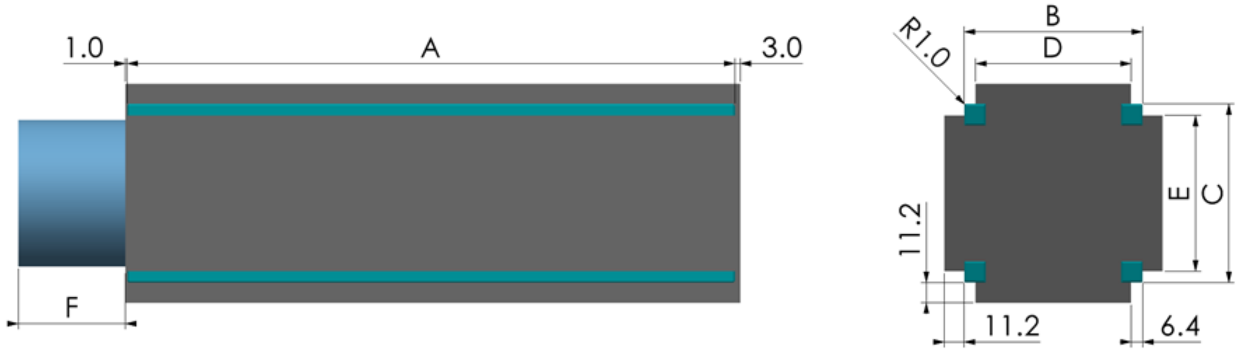


Figure 10: Maximum allowable outer dimensions for cubesats (3U) launched in an EXOpod Areas in contact with the deployer are highlighted in mint green

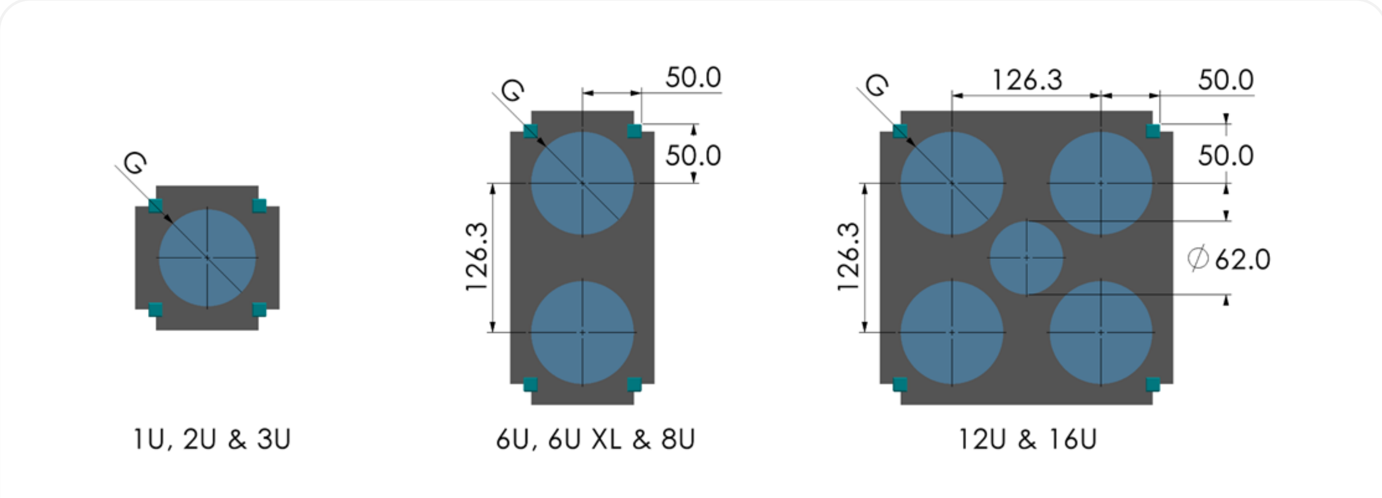


Figure 11: Maximum allowable tuna can dimensions for cubesats launched in an EXOpod

Table 1: Maximum cubesat dimensions

<table>
<tr><th colspan="2">Description</th><th>Units</th><th>Letter</th><th>3U</th><th>6U</th><th>6U XL</th><th>8U</th><th>12U</th><th>16U</th></tr>
<tr><td>Cubesat Rail Length (Z)</td><td>[±0.5 mm]</td><td rowspan="7">mm</td><td>A</td><td colspan="2">340.5</td><td>365.9</td><td>454.0</td><td>340.5</td><td>454.0</td></tr>
<tr><td>Cubesat Rail Width (X)</td><td>[±0.1 mm]</td><td>B</td><td>100.0</td><td>226.3</td><td colspan="2">226.3</td><td colspan="2" rowspan="2">226.3</td></tr>
<tr><td>Cubesat Rail Height (Y)</td><td>[±0.1 mm]</td><td>C</td><td colspan="2">100.0</td><td colspan="2">100.0</td></tr>
<tr><td colspan="2">Maximum Space Between Rails (X)</td><td>D</td><td>87.2</td><td>213.5</td><td colspan="2">213.5</td><td colspan="2" rowspan="2">213.5</td></tr>
<tr><td colspan="2">Maximum Space Between Rails (Y)</td><td>E</td><td colspan="2">87.2</td><td colspan="2">87.2</td></tr>
<tr><td colspan="2">12U EXOpod Tuna Can Depth
(Except 5. tuna can)</td><td rowspan="2">F</td><td colspan="2">58.0</td><td colspan="2">-</td><td>58.0</td><td>-</td></tr>
<tr><td colspan="2">16U EXOpod Tuna Can Depth
(Except 5. tuna can)</td><td colspan="2">-</td><td>77.0+*</td><td>77.0</td><td>-</td><td>77.0</td></tr>
<tr><td colspan="2">Tuna Can Diameter
(Except 5. tuna can)</td><td></td><td>G</td><td colspan="2">82.0</td><td>87.0+*</td><td>87.0</td><td>82.0</td><td>87.0</td></tr>
<tr><td colspan="2">5th Center Tuna Can Diameter</td><td></td><td>-</td><td colspan="4" rowspan="2">-</td><td colspan="2">62.0</td></tr>
<tr><td colspan="2">5th Center Tuna Can Depth</td><td></td><td>-</td><td colspan="2">60.0</td></tr>
<tr><td colspan="2">Number of Tuna Cans</td><td>-</td><td>-</td><td>1</td><td colspan="3">2</td><td colspan="2">5</td></tr>
<tr><td colspan="2">Distance Between Tuna Cans</td><td>mm</td><td>-</td><td>-</td><td colspan="5">126.3</td></tr>
<tr><td colspan="2">Maximum Mass, RPM</td><td rowspan="2">kg</td><td rowspan="2">-</td><td rowspan="2">6</td><td colspan="2" rowspan="2">12</td><td rowspan="2">15</td><td rowspan="2">22</td><td>24</td></tr>
<tr><td colspan="2">Maximum Mass, BPM</td><td>29</td></tr>
<tr><td colspan="2">Maximum Distance Between COG and Geometric Center</td><td rowspan="2">mm</td><td rowspan="2">-</td><td colspan="6">See Table 1</td></tr>
<tr><td colspan="2">Rail Parallelism</td><td colspan="6">0.05</td></tr>
<tr><td colspan="2">Surface Roughness</td><td>μm</td><td>-</td><td colspan="6">1.6</td></tr>
</table>

*** The adapter used to accommodate a 6U XL (see Figure 19) can be modified to fit custom dimensions**

The maximum recommended distance between the COG and the geometrical center is outlined in Table 2. All values are based on the CDS [AD-1]. For unique cubesat designs the deviations can be higher, however, this can lead to increased local loads on the satellite and higher tip-off rates.

Before integration the customer is required to measure the rails of the satellite to prevent any fitting issues. A measurement worksheet template can be provided by Exolaunch. For questions on custom designs and form factors please talk to Exolaunch.

Table 2: Maximum recommended distance of the COG from the geometrical center

Description	X-axis (mm)	Y-axis (mm)	Z-axis (mm)
1U	± 20	± 20	± 20
1.5U	± 20	± 20	± 30
2U	± 20	± 20	± 45
3U	± 20	± 20	± 70
6U / 6UXL	± 45	± 20	± 70
8U	± 45	± 20	± 95
12U	± 45	± 45	± 70
16U	± 45	± 45	± 95

2.4 Deployment Energy

The energy of the deployment spring E_{pot} and the accelerated mass, determines the deployment velocity v. The total accelerated mass includes the cubesat m, the springs $n*m_S$, the deployment wagon m_W and the slot adapter m_A (if applicable). An overview of the additional masses is listed in Table 3. Equation 1 approximates the deployment velocity v of the cubesat.

Table 3: Properties of the accelerated components

cubesat	1U	2U	3U	6U	6U XL	8U	12U	16U
Spring Mass (kg)	0.15			0.21			0.26	
Number of Springs (n)	1			2			4	
Mass of Deployment Wagon (m_W) [kg]	0.245			0.440			0.780	
Mass of Adapter (m_A) [kg]	0.555	0.508	0	0	0.230	0	0	0

$$v_{deploy} = \sqrt{\frac{2 \cdot E_{pot}}{m_{sat} + \frac{1}{2} \cdot n \cdot m_S + m_w + m_A}}$$

Equation 1: Approximation of the deployment velocity

$$E_{pot} = s \cdot (F_i + F_e)$$

Equation 2: Potential energy equation

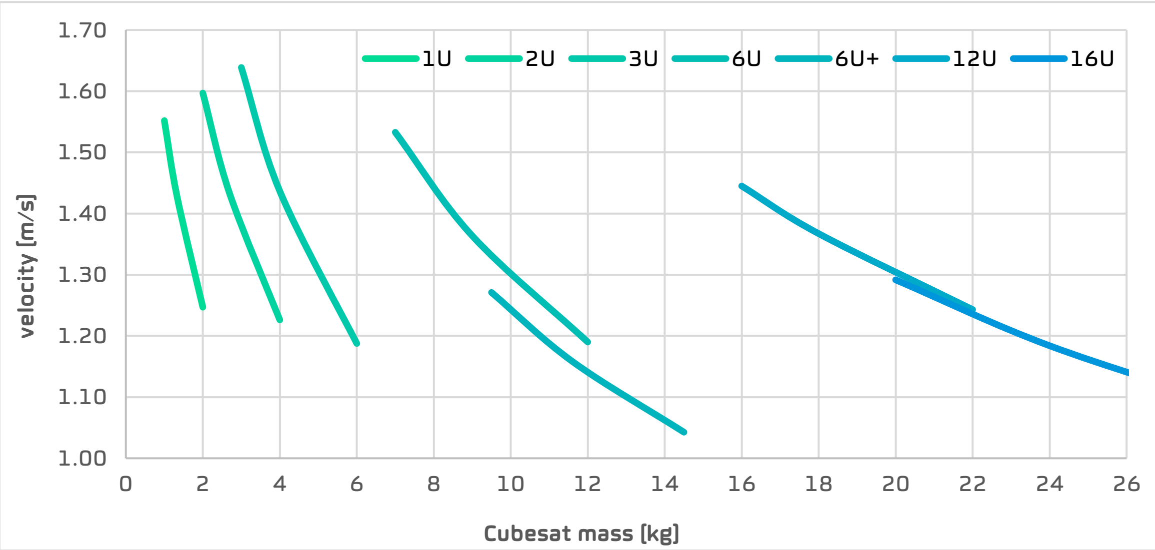
Each cubesat size has an own distinct spring energy, where the typical manufacturing tolerances are ±20%. After manufacturing, real values are measured and used for the ballistic analysis. The nominal values are shown in Table 4 and specific values can be discussed upon request.

Table 4: Properties of the standard deployment spring

cubesat	1U	2U	3U	6U	6U XL	8U	12U	16U
Initial force [N]	22.0	22.0	22.0	44.0	36.71	36.71	88.0	73.42
End force [N]	4.0	4.0	4.0	8.0	8.31	1.67	16.0	3.35
Stroke [m]	0.1157	0.2292	0.3427	0.3427	0.3681	0.4562	0.3427	0.4562
Potential energy [J] ±20%	2.19	3.68	4.46	8.91	8.31	8.76	17.82	17.51

The deployment velocity can be approximated for different cubesat masses, which is depicted in Figure 12. Note that the deployment wagon will only release after the door passes an opening angle of 95 deg, which translates to a time delay of 115 ms after the activation signal for the door release before the spring starts moving.

Figure 12: Approximate deployment velocities for different cubesat sizes



The ejection time, t, can be approximated using the equation provided below. Precise values of these times can be provided upon request.

$$t_{deploy} = \frac{\sin^{-1}\left(\frac{-s_{stowed}}{s_{\max\_spring}}\right) + \frac{\pi}{2}}{\omega_0}, where\ \omega_0 = \sqrt{\frac{F_i - F_e}{s_{stroke} \cdot m_{total}}}$$

Equation 3: Deployment velocity equation

2.5 Tip-Off Rates

Tip-off rates are expected to be below 10 deg/s for all cubesats in all axes. However, 3U long types have shown a tendency to be more stable. The separation half cone angle is ±7.5 deg.

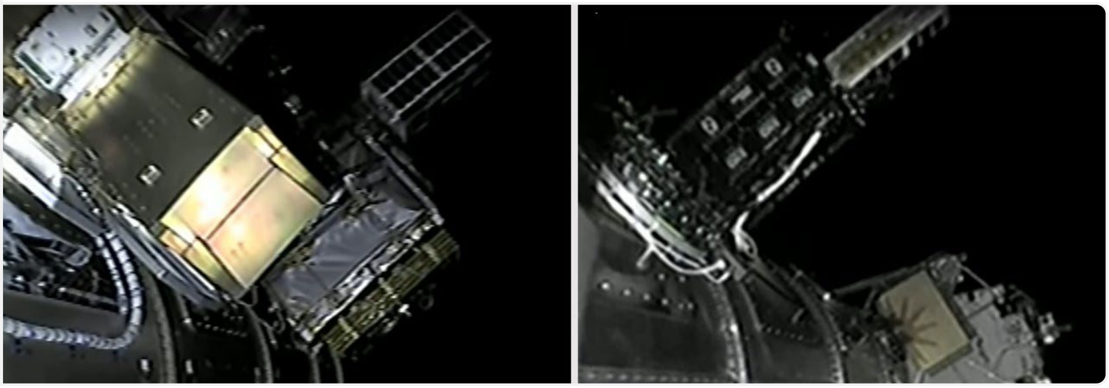


Figure 13: Deployment of a 16U cubesat during Transporter-5 (left) and a 3U cubesat during the Transporter-2 mission (Right)

3

Mechanical Properties

3.1 Coordinate System

The coordinate system of EXOpod is illustrated below. Where the coordinate system origin is in the center of the rear plate mounting interface plane (not including the rear mounting feet).

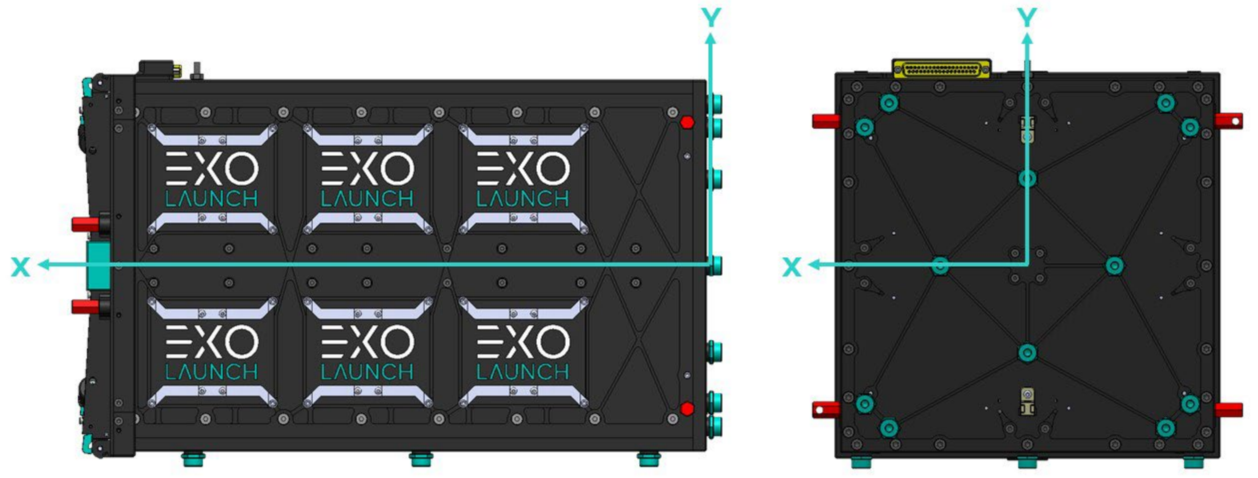


Figure 14: Coordinate System of the EXOpod

3.2 Mass Properties

The detailed mass properties for all EXOpod configurations are found with the appendix of this document, (Table 11 through Table 18) for 12U and (Table 19 through Table 22) for the 16U EXOpod. Configurations vary based on mounting orientation, number of slots, and open/closed state.

- EXOpod configurations: 12U/16U S1-S4, see Section 2.2
- Rear Plate Mounting (RPM) and Bottom Plate Mounting (BPM), see Section 4.1.1 and 4.1.2
- Open and Closed states: Illustrations located above tables in Appendix
- Access windows are included in all configurations
- Mounting fasteners are NOT included

Table 5: Mass of typical 12U/16U EXOpod configurations

EXOpod Configuration	Mass ±5% [kg]	
	Horizontal (BPM) Bottom Plate Mounting	Vertical/Horizontal (RPM) Rear Plate Mounting
12U S1	7.93	7.96
12U S2	9.43	9.47
12U S3	10.34	10.38
12U S4	11.22	11.26
16U S1	9.10	9.10
16U S2	10.85	10.85

3.3 Outer Dimensions

The outer dimensions of the 12U and 16U EXOpod variants are shown in Figure 15 and Figure 16 respectively.

Figure 15:
Outer dimensions of the opened and closed states of the 12U EXOpod

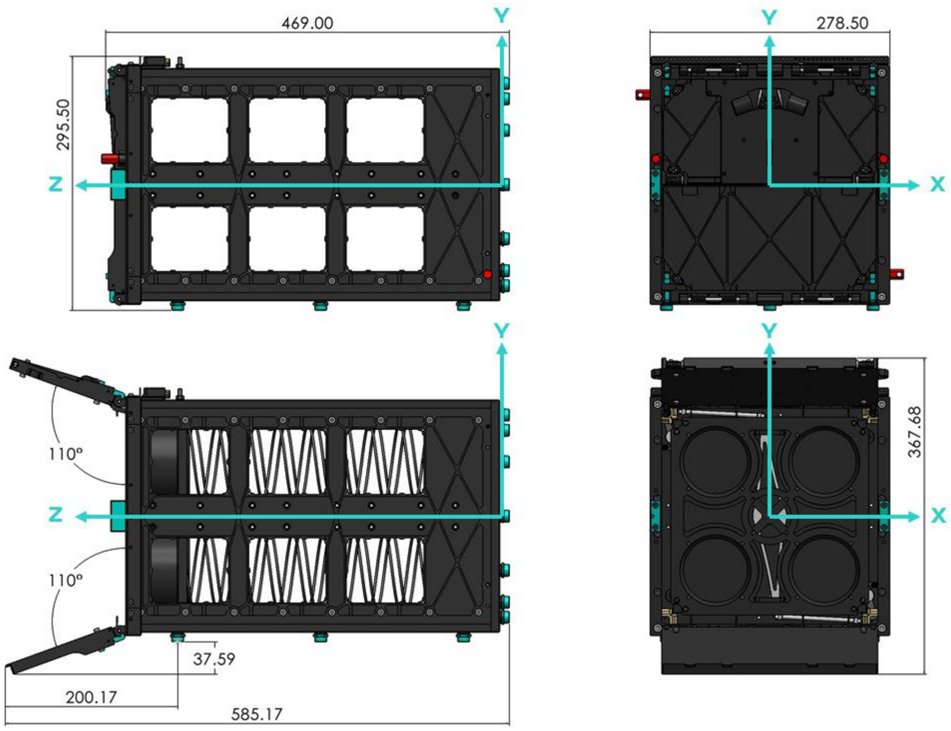
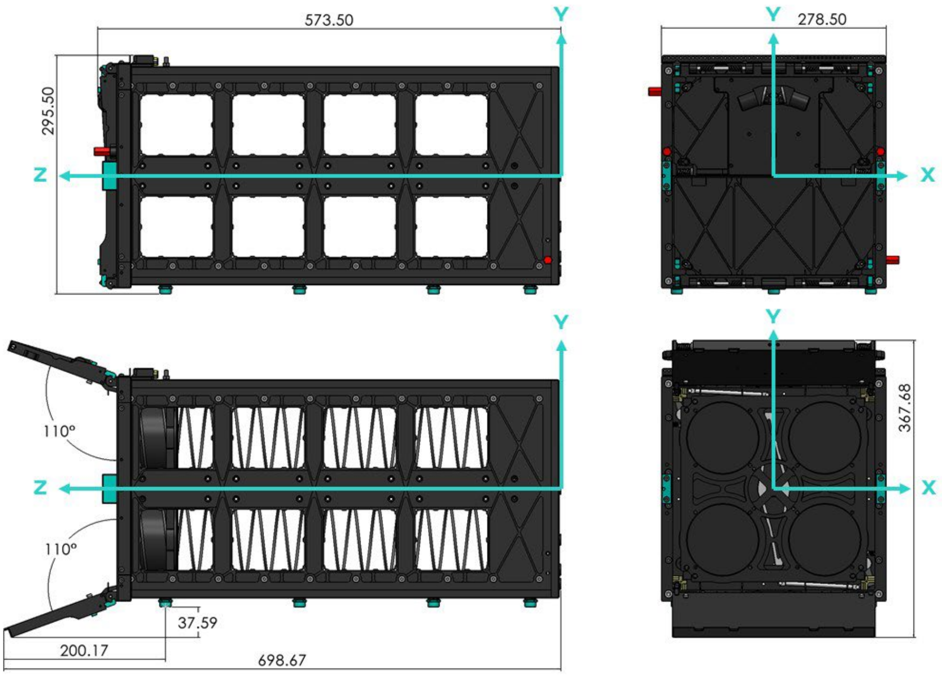


Figure 16:
Outer dimensions of the opened and closed states of the 16U EXOpod



3.4 Cubesat Adapters

To ensure that the EXOpod can accommodate for various cubesat formfactors, a variety of adapters have been developed to be implemented into the slots of the deployer. These adapters range from 1U to 6U, and feature latches which prevent their separation in space during deployment. Like the deployment wagon, an integrated magnet prompts the telemetry switches. The subsequent figures illustrate the most commonly used adapters offered by Exolaunch; other adapters can be provided upon request.

Further details concerning the mass properties of the cubesat adapters can be found within the Table 23.

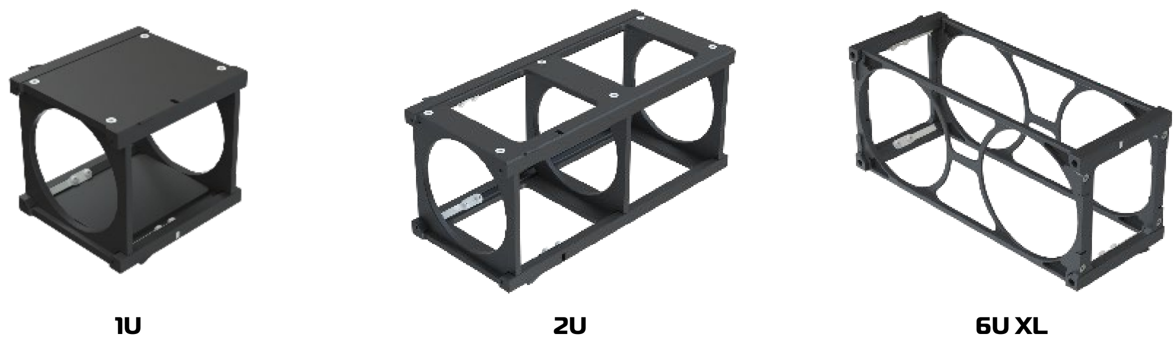


Figure 17: Illustration of EXOpod cubesat adapters

4

Mechanical Interfaces

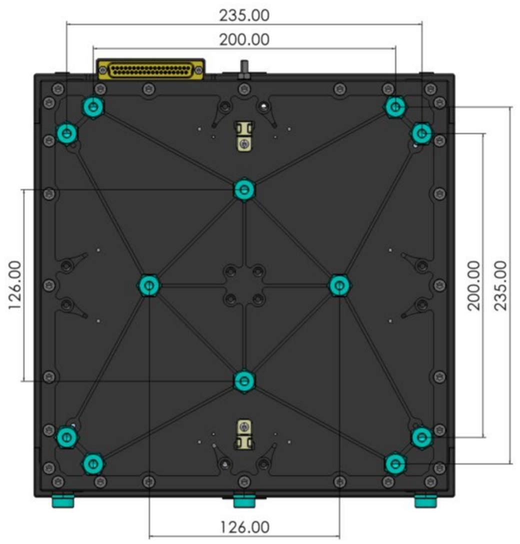
4.1 Launch Vehicle Interfaces

Both EXOpod variations feature mechanical interfaces on two sides of the chassis, allowing either a vertical (rear plate mounting, wall mounting) or a horizontal (bottom plate mounting, floor mounting) mounting orientations. Interface properties for all configurations are summarized in Table 6. Stainless steel screws in combination with Nord-Lock washers are recommended as fasteners for all EXOpod models for mounting to the launch vehicle interface. Please confer with Exolaunch regarding the use of other types of secondary retention or lubricants.

4.1.1 Rear Plate Mounting Interface

The mechanical interface for Rear Plate Mounting launch vehicle is shown in Figure 18.

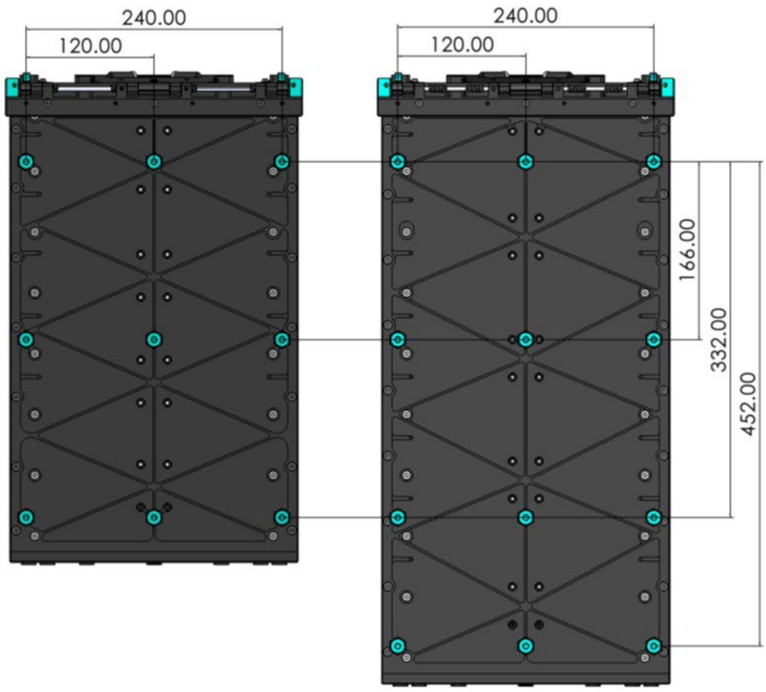
Figure 18:
Mounting hole pattern for the vertical configuration



4.1.2 Bottom Plate Mounting Interface

The mechanical interface for bottom Plate Mounting is shown in Figure 19.

Figure 19:
Bottom side mounting hole pattern on the 12U version (Left) and 16U version (Right)



4.1.3 Mounting Feet

The same type of mounting feet is used for both mounting orientations and on all EXOpods. A detailed view is shown in Figure 20, the mounting interface properties and fastener torque are further shown in Table 6.

Figure 20:
Detailed view of the mounting feet

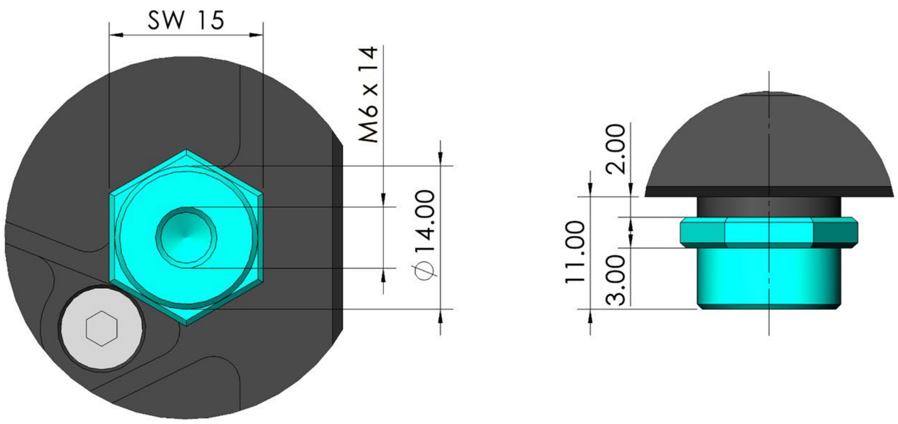


Table 6: Mechanical interface specification

	Vertical Mounting (Rear Plate Mounting, RPM)	Horizontal Mounting (Bottom Plate Mounting, BPM)	
Deployment	**Normal to mounting plane**	**Parallel to mounting plane**	
EXOpod model	**12U and 16U**	**12U**	**16U**
Mounting points	12	9	12
Tap hole	M6x14		
Fastener type	DIN 912 M6 A4-80 1.0 pitch (or stronger)		
Thread locker	Nord-Lock NL6ss		
Min. screw-in depth	9 mm		
Max. screw-in depth	13 mm		
Tightening torque - Mounting feet to launch vehicle interface	10.0 Nm		
Tightening torque - Feet to Deployer	20.0 Nm		
Contact area	12 x (OD 13.5 mm, ID 6 mm) = 1253 mm²	9 x (OD 13 mm, ID 6 mm) = 940 mm²	12 x (OD 13.5 mm, ID 6mm) = 1253 mm²
Surface finish	Ra 1.6		
Overall Flatness	< 0.1 mm		

4.1.4 Lifting Interface

The EXOpod provides two interfaces for installing lifting handles on the top (+Y) and front (+Z) faces. The handles facilitate the handling of the EXOpod by crane and moving in general. Handles must be used whenever the EXOpod is loaded. All surfaces of the deployers can be touched and be used for lifting. Wearing gloves is advised during handling of the deployer.

The handles are installed using M4 threaded thumb screws which can carry the weight of a fully loaded EXOpod with significant safety margin. Figure 21 shows an illustration of the lifting brackets.

Figure 21:
Lifting handles installed on the front and top faces

4.1.5 Grounding

The EXOpod provides a grounding connection to the launch vehicle through the mounting fasteners. Mating surfaces should be masked if the surfaces are to be coated to allow electrical connection.

4.1.6 Remove Before Flight Elements

The EXOpods features two sets of Remove Before Flight (RBF) pins to provide safety during ground handling, satellite integration and mounting of the EXOpod on the launch vehicle. One pin set secures the deployer doors; another set locks the deployment wagon in place, see Figure 22. This prevents premature spring release and facilitates the integration procedure (bottom pins in Figure 3). It is recommended to use the RBF pins during transportation and ground handling and the use of a spring RBF is mandatory during satellite integration.

Two RBF pins are necessary to fully secure a slot, one for the spring release mechanism and one for the door. Details concerning the use and tightening procedure of the RBF pin can be seen in the provided integration guide.

Figure 22: 12U S4 EXOpod with RBF pins attached (red). Two pins secure each slot: one pin secures the door and one pin locks the spring mechanism in place.

4.2 Satellite Interfaces

4.2.1 Rails and Clamping Mechanism

Cubesat rails are the primary interface between satellite and EXOpod. To compensate for loose manufacturing tolerances, Exolaunch utilizes an array of spring driven clamps along the guidance rails which restrain the satellite in both X and Y directions and prevent it from shaking and rattling during transportation and launch, see Figure 25. This mechanism engages as the door of the respective slot is closed and the clamping force increases linearly with a decreasing opening angle of the door.

The total clamping force of the mechanism varies dependent on the EXOpod configuration, the slot the satellite is integrated in, and the cubesat dimensions. 3U slots have a clamping system on a single rail (vertical and lateral combined), creating a diagonal clamping force. 6U, 6UXL and 8U slots have clamps on two rails, 12U and 16U slots on three. These different clamping scenarios are illustrated in Figure 24. Since the clamping mechanism is functionally connected to the door, in the case of all cubesat sizes up to 8U the slot dictates whether the satellite is clamped from the top or bottom, see Figure 24b).

In an ideal case, the total clamping force of one rail is distributed evenly between the clamping feet. Manufacturing driven variations in satellite rail flatness will lead to a minorly uneven distribution. If a cavity in the satellite's rails aligns with the position of clamping foot, the force will be distributed between the other feet. Equally, if the satellite is on the lower side of tolerances, the clamping force will be lower compared to a satellite on the upper side of tolerances. The resulting clamping force cases are summarized in Table 7.

Table 7: Clamping forces for different cubesat and slot sizes

	1U*	2U*	3U	6U	6UXL	8U	12U	16U
Number of rails with clamping feet	1			2			3	
Clamping force F_{cl} [N]	330 – 450			660 – 900			858 – 1170	
Distance between fully extended clamping foot (closed door) and opposing rails	99.75			225.50			226.05	

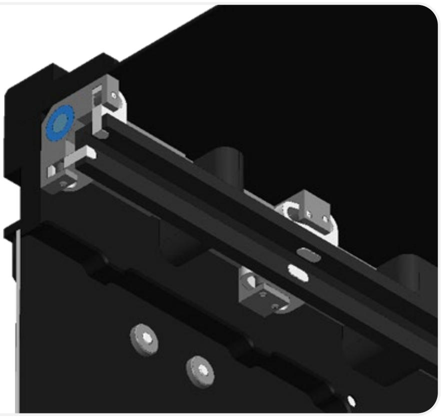
***1U and 2U cubesats will always share a slot either with other 1U/2U cubesats or with a non-deployable slot adapter. The clamping force will be distributed between all objects, effectively leading to a clamping scenario similar to that of a single 3U cubesat.**

The size and shape of the rails in all EXOpods are based on the CDS. Beyond that, rails on Exolaunch deployers only require cubesats to have a minimum rail width of 6.4 mm, compared to 8.5 mm established by the CDS, offering more space for the side panels on the cubesat. The rails are made of aluminum with Type III hard anodization with a surface roughness of $R_z = 4$.

Note the following:

- Rails on the cubesat must be **Type III hard anodized** to prevent cold welding, and to prevent wear on the rails during vibration. Any deviation from this surface finish, such as Type II anodizing or a chromate conversion dual finish, must be reported to and approved by Exolaunch in written form.
- Any edges or cavities in the cubesat rails shall be **adequately chamfered.**

Figure 23:
Clamping mechanism integrated in the guidance rails



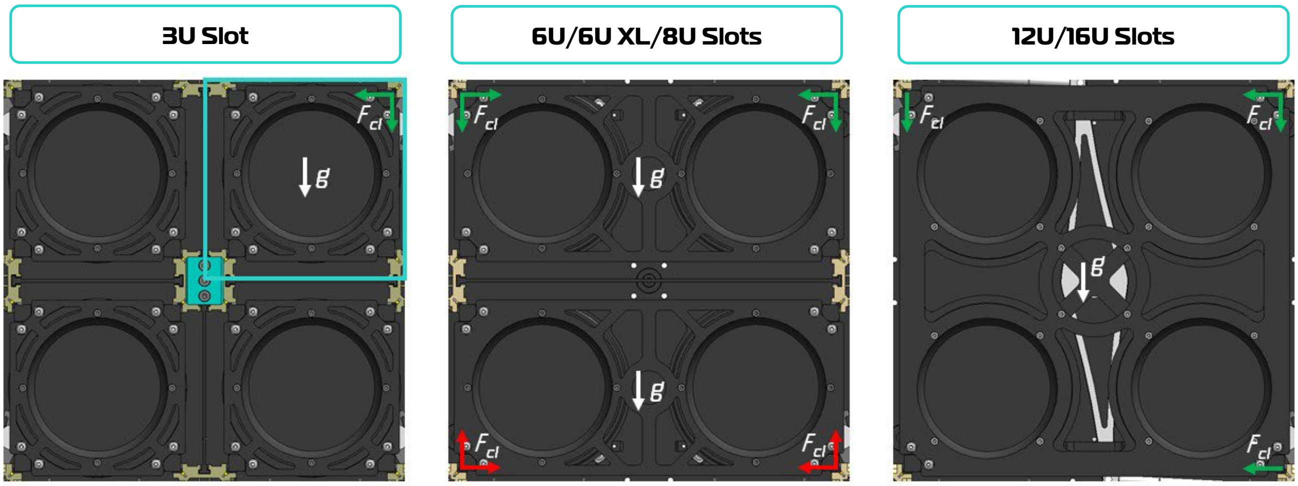
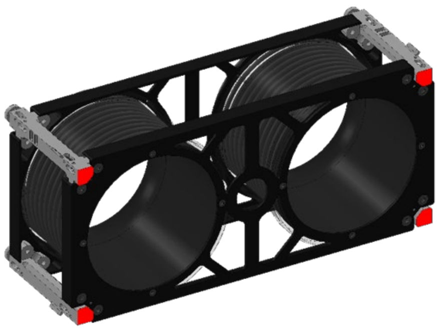


Figure 24: Clamping scenario based on slot size. A 3U cubesat can be clamped from any of the four corners depending on the slot it is integrated in

4.2.2 Deployment Wagon

The deployment wagon shown in Figure 25 is situated between the spring and cubesat, where it serves to keep the deployment springs in their correct orientation and ensuring a uniform transfer of the spring force onto the satellite.

Figure 25:
Deployment wagon of an S2 EXOpod carrying two springs for deployment of a 6U cubesat. Red areas in the left image indicate the contact points of the satellite



The deployment wagon is secured by its own clamping system. This mechanism will not release the spring/s until the door has opened past 90 degrees. This eliminates the possibility of the cubesat hitting the door during deployment.

4.2.3 Door with Set Screws

The cubesat is fixed in the Z-direction by the Deployment Wagon and the set screws located on the doors, see Figure 26. Before integration is performed the screws must be completely loosened. Once the satellite is placed inside the EXOpod, the door is then closed, and the set screws are to be carefully tightened to lock the satellite in place. To prevent the set screws from coming loose they are fixed by a toothed ring connected to a screw. Note that the set screws close the gap created by loose tolerances, but do not exert a clamping force on the satellite. The permittable protrusion from the front facing side of the cubesat as measured from the end of the rails is 3 mm. The specific tightening procedure can be found in the provided integration guide.

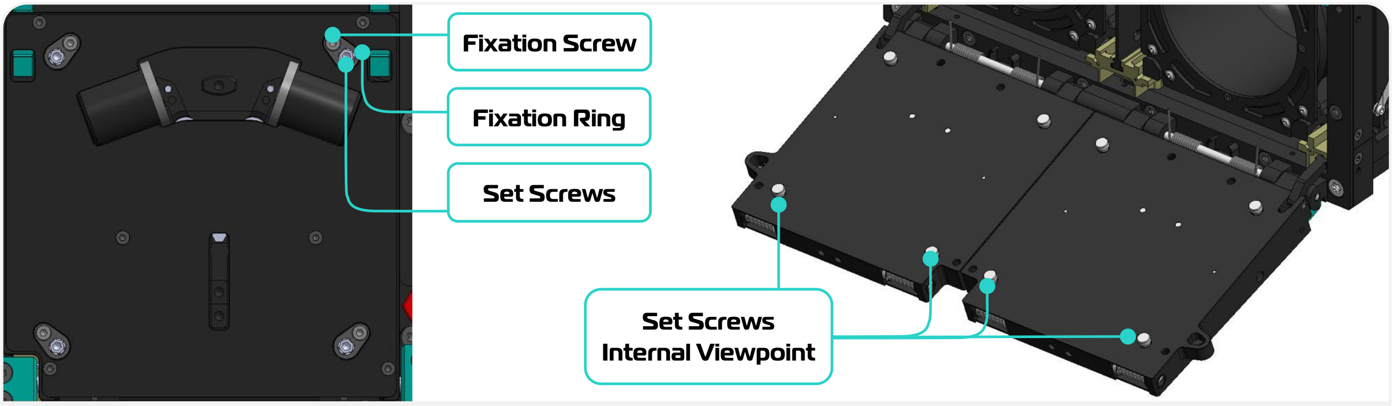


Figure 26: Left: Set screws as seen from the inside. Right: set screws as seen from the outside with fixation ring and screw

4.2.4 Access Windows

To allow for easy and quick access to the satellite during any point during or after integration, access windows are positioned on the right and left sides of the EXOpod. This allows charging of the satellite, access to external ports and last-minute removal of RBF pins. An illustration of the exact dimensions and locations of the windows are shown in Figure 27, these dimensions are equivalent for the 12U EXOpod although feature one less column of windows.

The measurements are taken from the Deployment Wagon (satellite contact plane, highlighted in red) along the guidance rails, which are the lateral contact planes of the cubesat – see detailed view in Figure 27.

These access window covers are comprised of an anodized aluminum body, which are secured by an array of screws. No thread locker is required when securing the access windows and to facilitate removal and handling, a steel bracket is used to hold the screws in place. A separate cubesat integration guide will be provided by Exolaunch.

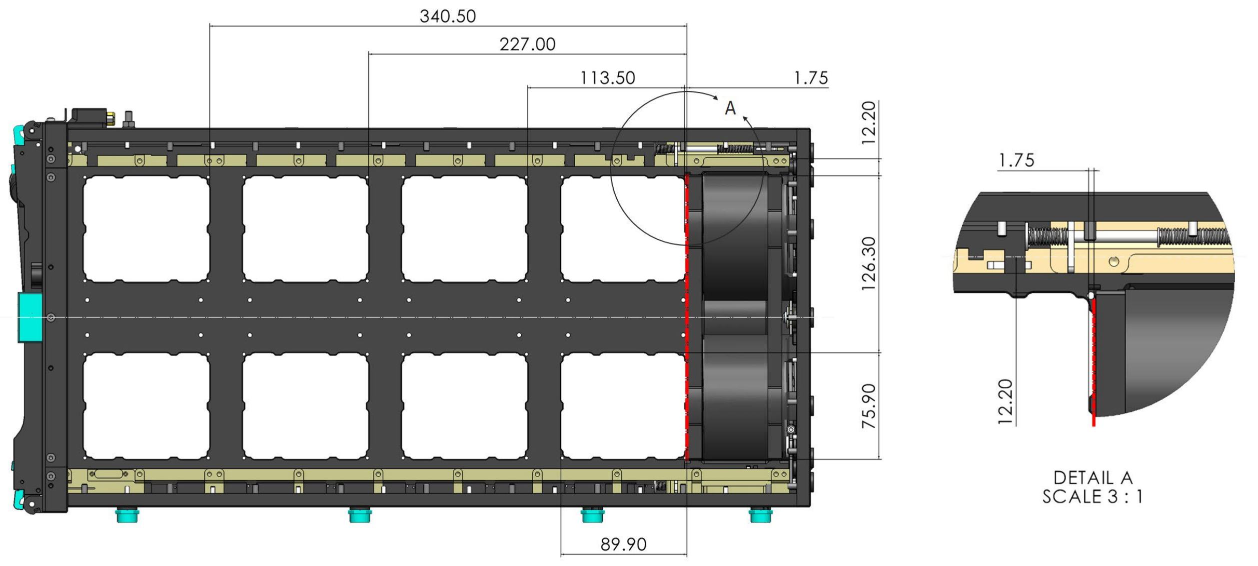


Figure 27: (Left) Position and Dimensions of the access windows of the 16U EXOpod. The 12U EXOpod is identical with three instead of four pairs of windows on each side. (Right) Detailed view A: Position of access window relative to the satellite contact plane

5

Electrical Interfaces

5.1 Electro-Magnetic Locks

The EXOpod features a unique electro-magnetic lock system which can be released by an electrical input signal from the launch vehicle. This particular type of locking system is used across all Exolaunch separation systems and has extensive flight heritage from over 200 successful deployments in space and an order of magnitude more when taking into account ground operations and testing environments.

A magnetic lock has significant advantages over other existing solutions on the market including burnwire mechanisms or motorized locks. It provides maximum user-friendliness allowing fast engagement and release, functional testing within seconds and can be operated using COTS tooling. For maximum reliability, each door uses two redundant locks that can trigger the opening independently.

The standard required deploy signal characteristics (28VDC, 230mA, 130ms) can be provided by almost any launch provider with modifications.

The internal spring mechanism is mechanically connected to the door and will only release once the door reaches an opening angle greater than 90°. This prevents the satellite from impacting the door during deployment. A latching mechanism prevents rebounding once the door has fully opened.

5.2 Electrical Connectors

Each slot of EXOpod has two magnetic locks acting as redundant actuators, as well as two Reed switches that indicate the state of the deployment system. One reed switch indicates the position of the deployment wagon, while a second tracks the status of the door. Both switches are Normally Open (NO), meaning that the first switch circuit closes when the deployer door has fully opened, and the second Reed switch closes when the deployment wagon reaches the front of the deployer slot.

For electrical connectivity, EXOpod is equipped with a D-Sub 37-pin male connector **(ITT Cannon DCMA37P),** which serves as the primary electrical interface (see Figure 28). The connector pinout is shown in Table 8, and the corresponding slot numbers are indicated in Figure 29. The electrical signal characteristics for operating EXOpod are summarized in Table 9. Exolaunch recommends that a D-Sub 37-pin female connector from **CONEC (part number 164X11799X)** to be used for the electrical harness.

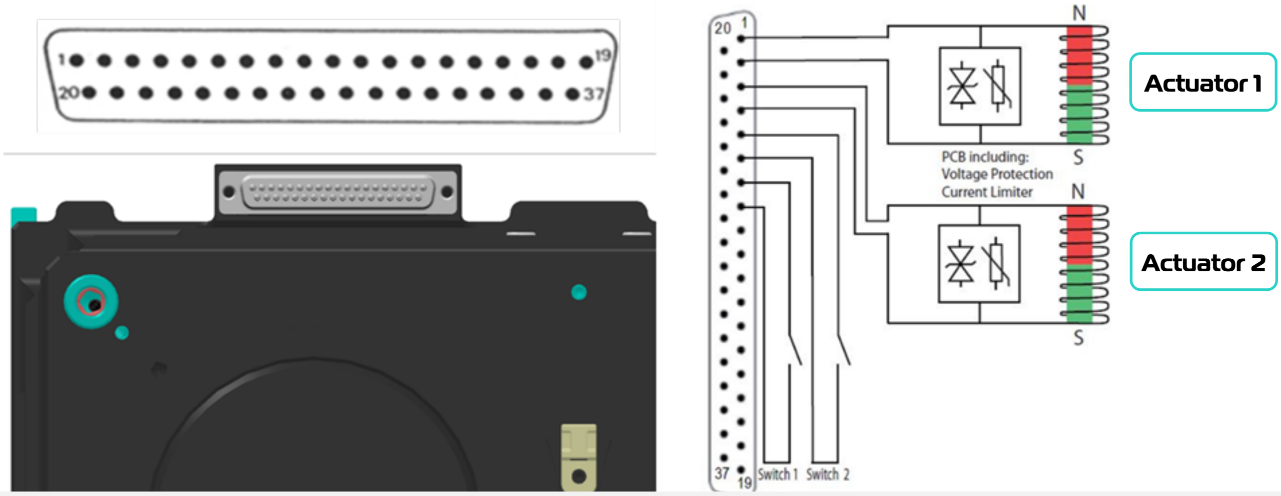


Figure 28: Left: DCMA37P connector on EXOpod top side (+Y) and pin assignment. Right: Actuator diagram

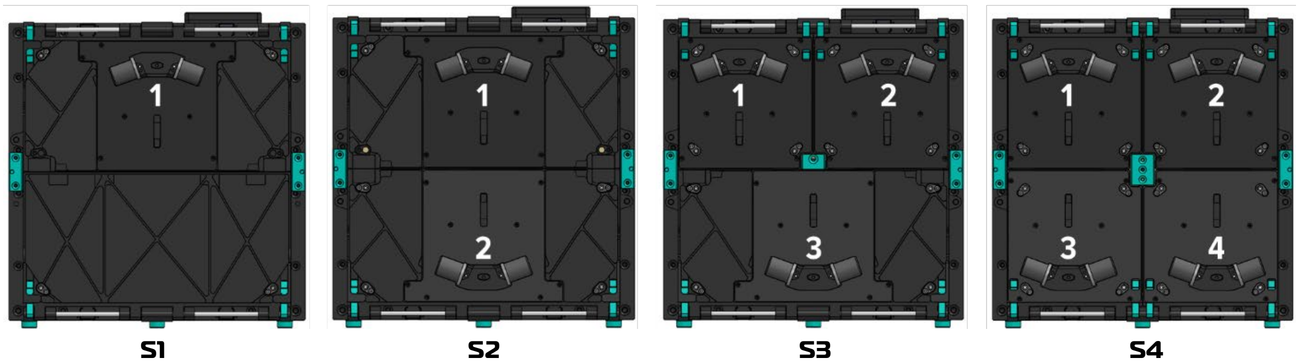
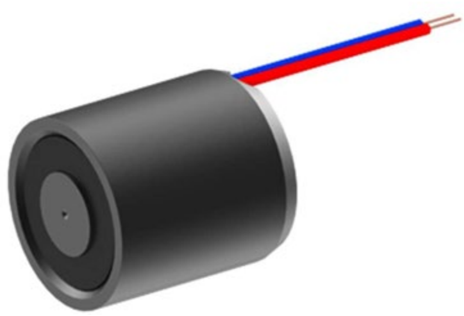


Figure 29: EXOpod slot numbers corresponding to the pin assignment in Table 24

Table 8: Characteristics of the electrical signal

Parameters	Value	Permanent Magnet
Actuating Voltage	Nominal: 28±4 VDC	
	Max: 50 VDC	
Pulse Duration	Min: 0.130 s	
	Nominal: 0.5 sec	
	Max: 3 sec every 30 sec	
Current	No-fire: 112 mA	
	Nominal: 280 mA	
	Max: 500 mA	
Resistance	100 Ohm ± 5%	
Actuator Inductance	32mH±10% in closed state	
	40mH±10% in open state	

All EXOpods utilize cable guides on the top and rear faces of the deployer, to securely fasten the harness to the chassis. Zip ties are used to fasten the cable to the cable guides. The guides are made from PEEK, a robust plastic with low outgassing properties.

Figure 30:
The cable guides secure the cable to the EXOpod chassis when mounted on the launch vehicle

6

Thermal Interfaces

6.1 Thermal Qualification

To guarantee flawless performance in space, the EXOpod has been qualified under the environments listed in Table 9, including the addition of multiple successful functional tests.

Table 9: Magnetic lock thermal qualification environment

System level	Test		Conditions
Magnetic lock	Thermal Cycling		27 cycles alternating between -34°C and +71°C
EXOpod	Operational	T_{MAX}	+71°C
		T_{MIN}	-34°C
	Non-operational	T_{MAX}	+120°C
		T_{MIN}	-54°C

6.2 Satellite Interfaces

The heat transfer between cubesat and EXOpod relies on heat conduction through the guiding rails, deployment wagon and set screws.

6.3 Launcher Interfaces

The EXOpod is not actively thermally controlled. A conductive thermal path is achieved through the mounting interface. The passive thermal properties are summarized in Table 10.

Table 10: Thermal interface

	Rear plate mounting	Bottom plate mounting	
Mounting interface			
Contact area	12 feet = 1253 mm²	12U	16U
		9 feet = 940 mm²	12 feet = 1253 mm²
Material	Green Anodized Aluminum 5083		
Chassis			
Total radiating area	0.6 m²		
Surface (≥ 96%)	Black anodized Aluminum 5083 Emissivity (ε) ≈ 0.88 Absorption (α) ≈ 0.88		

7

Integration and Transportation

7.1 Cubesat Integration

The integration procedure for EXOpod is described in detail in [AD-3]. Please contact Exolaunch if further detail is required.

7.2 Transportation and Storage

To ensure safe storage and transportation, EXOpod is stored and transported inside a Pelican Case with a laser-cut foam shell. For the shipment to the launch site, EXOpod is placed in an ESD bag with desiccant. Shock sensors are attached to the case, and the case is then strapped onto a half pallet.

During transportation the springs must be in their stowed state and secured using the provided RBF pins, while in storage the EXOpod should be in its deployed state whenever possible. Before satellite integration, EXOpod is cleaned inside a cleanroom to standard ISO class 8 cleanliness requirements.

Figure 31: EXOpod Nova deployer placed in its custom safety case and secured for shipment (Shock sensors not shown). Identical concept used for the EXOpod.

A

Appendix

12U EXOpod Mass Properties

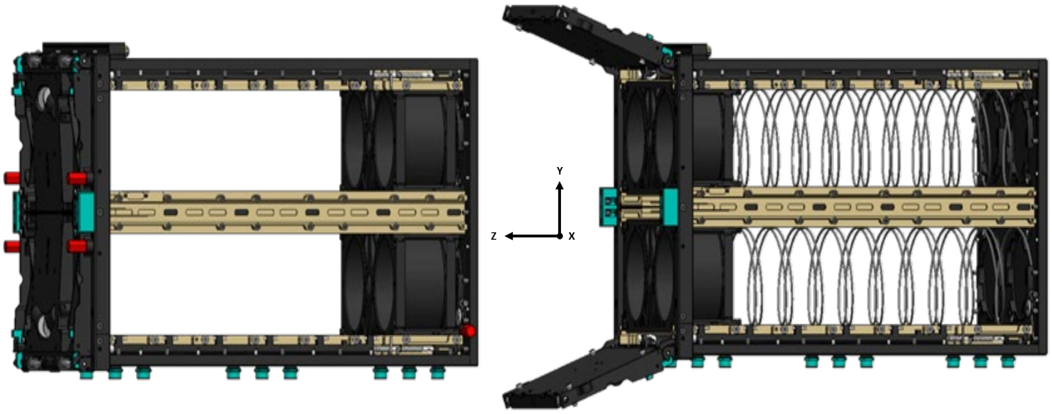


Figure 33: EXOpod 12U Bottom Plate Mounting configuration, in both closed (Left) and open (Right) states

Table 11: Mass properties of the 12U S1 EXOpod for the Bottom Plate Mounting (BPM) scenario

S1	Closed		Open		Unit
Mass (±5%)	7.93				kg
Center of Gravity	X	-1.75	X	-1.75	mm
	Y	5.03	Y	8.47	
	Z	211.36	Z	262.91	
Moments of Inertia rel. to COG	I_{XX}	305000	I_{XX}	329000	kgmm²
	I_{YY}	305000	I_{YY}	314000	
	I_{ZZ}	160000	I_{ZZ}	175000	
Product of Inertia rel. to COG	I_{XY}	7342.25	I_{XY}	13137.95	kgmm²
	I_{XZ}	677.34	I_{XZ}	1280.00	
	I_{YZ}	1948.67	I_{YZ}	1970.01	

Table 12: Mass properties of the 12U S2 EXOpod for the Bottom Plate Mounting (BPM) scenario

S2	Closed		Open		Unit
Mass (±5%)	9.43				kg
Center of Gravity	X	0.38	X	0.38	mm
	Y	0.08	Y	0.08	
	Z	219.90	Z	269.43	
Moments of Inertia rel. to COG	I_{XX}	341000	I_{XX}	372000	kgmm²
	I_{YY}	348000	I_{YY}	358000	
	I_{ZZ}	175000	I_{ZZ}	196000	
Product of Inertia rel. to COG	I_{XY}	2277.66	I_{XY}	2241.88	kgmm²
	I_{XZ}	638.03	I_{XZ}	461.62	
	I_{YZ}	-55.41	I_{YZ}	-58.84	

Table 13: Mass properties of the 12U S3 EXOpod for the Bottom Plate Mounting (BPM) scenario

S3	Closed		Open		Unit
Mass (±5%)	10.34				kg
Center of Gravity	X	0.61	X	0.62	mm
	Y	6.23	Y	7.86	
	Z	224.73	Z	272.44	
Moments of Inertia rel. to COG	I_{XX}	371000	I_{XX}	405000	kgmm²
	I_{YY}	375000	I_{YY}	384000	
	I_{ZZ}	183000	I_{ZZ}	207000	
Product of Inertia rel. to COG	I_{XY}	5986.39	I_{XY}	8428.95	kgmm²
	I_{XZ}	380.09	I_{XZ}	76.79	
	I_{YZ}	179.31	I_{YZ}	167.24	

Table 14: Mass properties of the 12U S4 EXOpod for the Bottom Plate Mounting (BPM) scenario

S4	Closed		Open		Unit
Mass (±5%)	11.22				kg
Center of Gravity	X	0.32	X	0.32	mm
	Y	0.07	Y	0.07	
	Z	228.97	Z	275.25	
Moments of Inertia rel. to COG	I_{XX}	401000	I_{XX}	439000	kgmm²
	I_{YY}	400000	I_{YY}	410000	
	I_{ZZ}	191000	I_{ZZ}	220000	
Product of Inertia rel. to COG	I_{XY}	2271.12	I_{XY}	2237.70	kgmm²
	I_{XZ}	605.73	I_{XZ}	440.88	
	I_{YZ}	491.52	I_{YZ}	491.39	

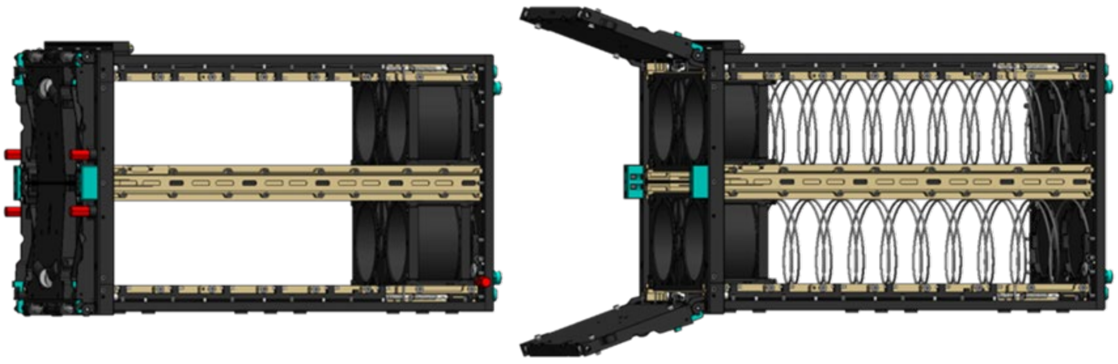


Figure 34: EXOpod 12U Rear Plate Mounting configuration, in both closed (Left) and open (Right) states

Table 15: Mass properties of the 12U S1 EXOpod for the Rear Plate Mounting (RPM) scenario

S1	Closed		Open		Unit
Mass (±5%)	7.96				kg
Center of Gravity	X	-1.75	X	-1.75	mm
	Y	5.86	Y	9.28	
	Z	209.66	Z	261.10	
Moments of Inertia rel. to COG	I_{XX}	307000	I_{XX}	332000	kgmm²
	I_{YY}	307000	I_{YY}	317000	
	I_{ZZ}	160000	I_{ZZ}	174000	
Product of Inertia rel. to COG	I_{XY}	7398.87	I_{XY}	12908.32	kgmm²
	I_{XZ}	653.84	I_{XZ}	1255.07	
	I_{YZ}	1960.05	I_{YZ}	1981.30	

Table 16: Mass properties of the 12U S2 EXOpod for the Rear Plate Mounting (RPM) scenario

S2	Closed		Open		Unit
Mass (±5%)	9.47				kg
Center of Gravity	X	0.38	X	0.38	mm
	Y	0.79	Y	0.79	
	Z	218.44	Z	267.88	
Moments of Inertia rel. to COG	I_{XX}	343000	I_{XX}	375000	kgmm²
	I_{YY}	351000	I_{YY}	362000	
	I_{ZZ}	175000	I_{ZZ}	196000	
Product of Inertia rel. to COG	I_{XY}	2209.91	I_{XY}	1848.09	kgmm²
	I_{XZ}	643.24	I_{XZ}	467.13	
	I_{YZ}	-57.94	I_{YZ}	-61.37	

Table 17: Mass properties of the 12U S3 EXOpod for the Rear Plate Mounting (RPM) scenario

S3	Closed		Open		Unit
Mass (±5%)	10.38				kg
Center of Gravity	X	0.61	X	0.61	mm
	Y	6.87	Y	8.49	
	Z	223.39	Z	271.03	
Moments of Inertia rel. to COG	I_{XX}	373000	I_{XX}	408000	kgmm²
	I_{YY}	377000	I_{YY}	388000	
	I_{ZZ}	183000	I_{ZZ}	207000	
Product of Inertia rel. to COG	I_{XY}	5969.92	I_{XY}	8126.41	kgmm²
	I_{XZ}	388.48	I_{XZ}	85.66	
	I_{YZ}	175.33	I_{YZ}	163.26	

Table 18: Mass properties of the 12U S4 EXOpod for the Rear Plate Mounting (RPM) scenario

S4	Closed		Open		Unit
Mass (±5%)	11.26				kg
Center of Gravity	X	0.32	X	0.32	mm
	Y	0.66	Y	0.66	
	Z	227.73	Z	273.95	
Moments of Inertia rel. to COG	I_{XX}	404000	I_{XX}	442000	kgmm²
	I_{YY}	403000	I_{YY}	413000	
	I_{ZZ}	191000	I_{ZZ}	219000	
Product of Inertia rel. to COG	I_{XY}	2141.93	I_{XY}	1803.73	kgmm²
	I_{XZ}	610.15	I_{XZ}	445.53	
	I_{YZ}	489.40	I_{YZ}	489.28	

B

Appendix

16U EXOpod
Mass Properties

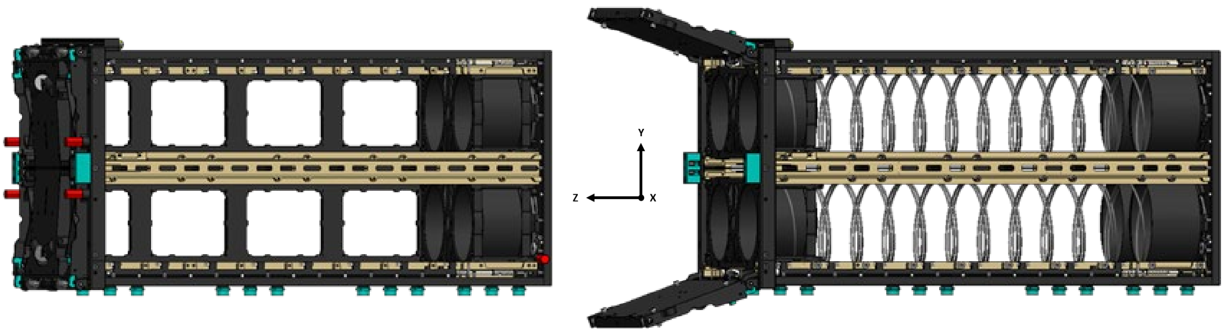


Figure 35: EXOpod 16U Bottom Plate Mounting configuration, in both closed (Left) and open (Right) states

Table 19: Mass properties of the 16U S1 EXOpod for the Bottom Plate Mounting (BPM) scenario

S1	Closed		Open		Unit
Mass (±5%)	9.10				kg
Center of Gravity	X	-2.08	X	-2.08	mm
	Y	4.55	Y	7.42	
	Z	257.07	Z	313.26	
Moments of Inertia rel. to COG	I_{XX}	498000	I_{XX}	512000	kgmm²
	I_{YY}	499000	I_{YY}	498000	
	I_{ZZ}	188000	I_{ZZ}	203000	
Product of Inertia rel. to COG	I_{XY}	9509.55	I_{XY}	16494.25	kgmm²
	I_{XZ}	785.03	I_{XZ}	1515.03	
	I_{YZ}	2421.35	I_{YZ}	2455.20	

Table 20: Mass properties of the 16U S2 EXOpod for the Bottom Plate Mounting (BPM) scenario

S2	Closed		Open		Unit
Mass (±5%)	10.85				kg
Center of Gravity	X	0.29	X	0.29	mm
	Y	-0.19	Y	-0.19	
	Z	268.43	Z	321.48	
Moments of Inertia rel. to COG	I_{XX}	562000	I_{XX}	583000	kgmm²
	I_{YY}	573000	I_{YY}	572000	
	I_{ZZ}	206000	I_{ZZ}	227000	
Product of Inertia rel. to COG	I_{XY}	2833.51	I_{XY}	2945.01	kgmm²
	I_{XZ}	958.01	I_{XZ}	592.19	
	I_{YZ}	-161.00	I_{YZ}	-159.80	

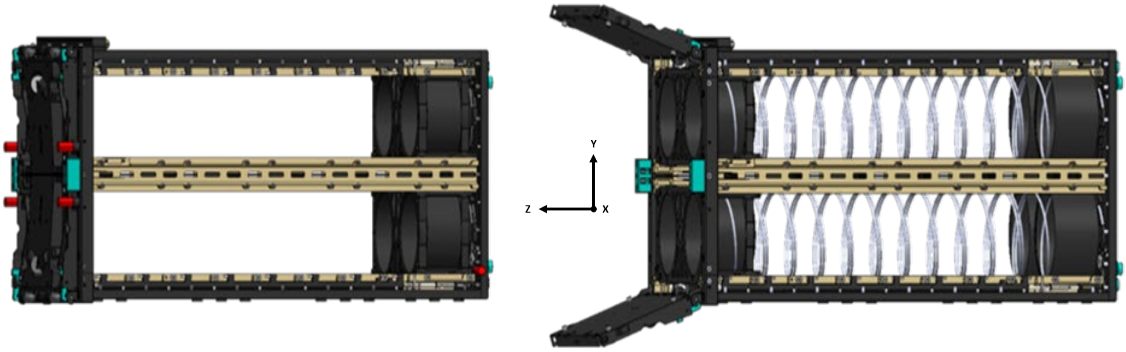


Figure 36: EXOpod 16U Rear Plate Mounting configuration, in both closed (Left) and open (Right) states

Table 21: Mass properties of the 16U S1 EXOpod for the Rear Plate Mounting (RPM) scenario

S1	Closed		Open		Unit
Mass (±5%)	9.10				kg
Center of Gravity	X	-2.08	X	-2.08	mm
	Y	5.51	Y	8.38	
	Z	255.31	Z	311.50	
Moments of Inertia rel. to COG	I_{XX}	500000	I_{XX}	515000	kgmm²
	I_{YY}	501000	I_{YY}	503000	
	I_{ZZ}	187000	I_{ZZ}	202000	
Product of Inertia rel. to COG	I_{XY}	9535.89	I_{XY}	16072.68	kgmm²
	I_{XZ}	751.59	I_{XZ}	1481.62	
	I_{YZ}	2439.65	I_{YZ}	2473.49	

Table 22: Mass properties of the 16U S2 EXOpod for the Rear Plate Mounting scenario

S2	Closed		Open		Unit
Mass (±5%)	10.85				kg
Center of Gravity	X	0.28	X	0.29	mm
	Y	0.63	Y	0.63	
	Z	266.94	Z	319.99	
Moments of Inertia rel. to COG	I_{XX}	564000	I_{XX}	587000	kgmm²
	I_{YY}	575000	I_{YY}	577000	
	I_{ZZ}	205000	I_{ZZ}	226000	
Product of Inertia rel. to COG	I_{XY}	2681.61	I_{XY}	2326.62	kgmm²
	I_{XZ}	962.59	I_{XZ}	596.78	
	I_{YZ}	-163.50	I_{YZ}	-162.31	

C

Appendix

EXOpod cubesat Adapter Mass Properties

Table 23: Mechanical Properties of standard cubesat slot adapters

Adapter	1U		2U		6U XL		Units
							
Mass	0.556		0.506		0.230		kg
Center of Gravity	X	-0.05	X	-0.05	X	-0.28	mm
	Y	-0.05	Y	-0.06	Y	0.11	
	Z	56.79	Z	117.03	Z	45.43	
Moments of Inertia rel. to COG	I_{XX}	1201.43	I_{XX}	3582.53	I_{XX}	629.84	$kgmm^2$
	I_{YY}	1701.53	I_{YY}	3783.82	I_{YY}	2418.96	
	I_{ZZ}	1609.87	I_{ZZ}	1632.55	I_{ZZ}	2547.05	
Product of Inertia rel. to COG	I_{XY}	-0.17	I_{XY}	-1.64	I_{XY}	-0.2	$kgmm^2$
	I_{XZ}	-0.16	I_{XZ}	-1.58	I_{XZ}	0.48	
	I_{YZ}	1.24	I_{YZ}	1.24	I_{YZ}	-2.9	

D

Appendix

DSub 37 connector pinout

Table 24: DSub 37 connector pinout. Green cells indicate that the pins for this slot are used in the respective configuration

Pin	Slot 1	Function	EXOpod Configuration				Remarks
			S1	S2	S3	S4	
1	Slot 1	Actuator 1	Y	Y	Y	Y	VCC
2		Actuator 1					Return
3		Actuator 2					VCC
4		Actuator 2					Return
5		Telemetry 1					Deployment Wagon status. Closed after deployment
6		Telemetry 1					
7		Telemetry 2					Deployment Wagon status. Closed after deployment
8		Telemetry 2					
9		x					not connected
10		x					not connected
11		x					not connected
12	Slot 2	Actuator 1	N	Y	Y	Y	VCC
13		Actuator 1					Return
14		Actuator 2					VCC
15		Actuator 2					Return
16		Telemetry 1					Deployment Wagon status. Closed after deployment
17		Telemetry 1					
18		Telemetry 2					Deployment Wagon status. Closed after deployment
19		Telemetry 2					
20	Slot 3	Actuator 1	N	N	Y	Y	VCC
21		Actuator 1					Return
22		Actuator 2					VCC
23		Actuator 2					Return
24		Telemetry 1					Deployment Wagon status. Closed after deployment
25		Telemetry 1					
26		Telemetry 2					Deployment Wagon status. Closed after deployment
27		Telemetry 2					
28		x					not connected
29		x					not connected
30	Slot 4	Actuator 1	N	N	N	Y	VCC
31		Actuator 1					Return
32		Actuator 2					VCC
33		Actuator 2					Return
34		Telemetry 1					Deployment Wagon status. Closed after deployment
35		Telemetry 1					
36		Telemetry 2					Deployment Wagon status. Closed after deployment
37		Telemetry 2					

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