

This is a standalone specification intended for payload designers. Planetary Systems Corporation does not design or manufacture payloads.

FEATURES AND BENEFITS

- **Preloaded Payload Tabs** create a modelable load path to the payload so strength at critical locations like reaction wheel bearings can be accurately calculated. Preload means the payload can't jiggle and damage itself.
- **Separation Electrical Connector** allows communication and charging between payload and launch vehicle prior to and during launch. It also grounds the payload to the CSD
- **Dispenser Constrained Deployables** greatly reduce the costs and complexity of payload deployables like solar panels and antennas.
- **Largest Volume** versus existing designs accommodates larger payloads. Payloads have 15% more volume and can be 1 inch longer than standard CubeSats.
- **Unrestricted External Shape** eliminates need for four corner rails.
- **Safe/Arm Access on Front** ensures payload access at all times via CSD door.
- **Flight Validated** in 2013.
- **Fully Documented** mechanical and electrical interfaces and CAD models available on request allowing rapid and low cost design.
- **Parametric Design** commonality allows users easy understanding of electro-mechanical interface for 3U, 6U, 12U and 27U sizes.
- **Cross Compatible** with existing CubeSat standards via tab attachment.

DESCRIPTION

These payloads are fully contained within a Canisterized Satellite Dispenser (CSD, canister or dispenser) during launch. A CSD encapsulates the payload during launch and dispenses it on orbit. CSDs reduce risk to the primary payload and therefore maximize potential launch opportunity. They also ease restrictions on payload materials and components. This specification currently encompasses four payload sizes, 3U, 6U, 12U and 27U.

The payloads incorporate two tabs running the length of the ejection axis. The CSD will grip these tabs, providing a secure, modelable, preloaded junction. This is essential to accurately predict loads on critical components and instrumentation and prevent jiggling.

The payload may use the CSD to restrain deployables. The allowable contact zones are defined.

A payload can be built to this specification without knowledge of the specific dispenser within it will fly. Similarly, dispenser manufacturers will be ensured of compatibility with payloads that conform to this specification.

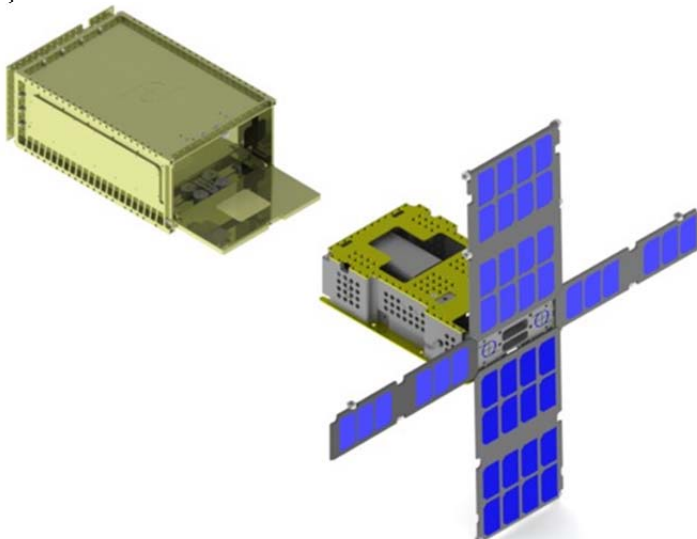


Figure 1: Payload Deploying from CSD

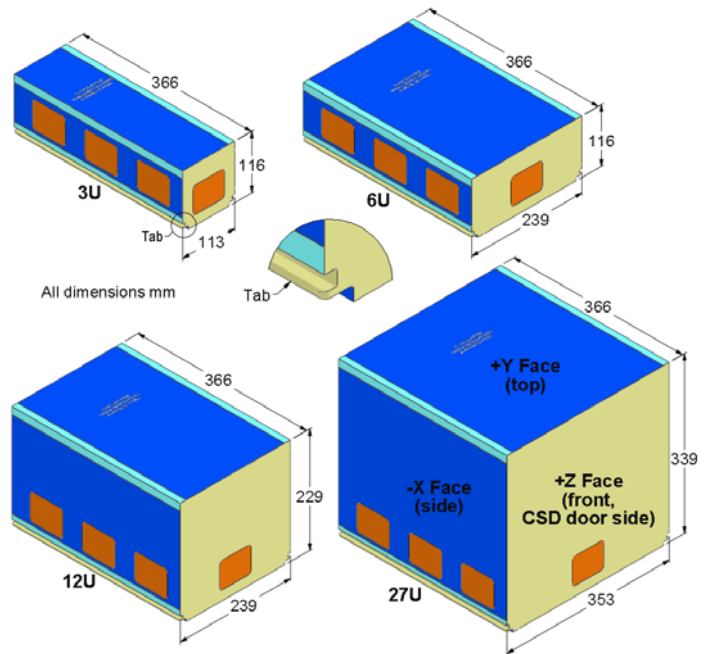


Figure 2: Payloads

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PARAMETERS

Symbol	Parameter	Conditions	Unit	3U		6U		12U		27U	
				Min	Max	Min	Max	Min	Max	Min	Max
M	Mass	At launch	kg [lb]	0	6.0 [13.2]	0	12.0 [26.4]	0	24.0 [52.9]	0	54.0 [119.0]
CM _x	Center of mass, X	Stowed in CSD	mm [in]	-20 [-0.79]	20 [0.79]	-40 [-1.57]	40 [1.57]	-40 [-1.57]	40 [1.57]	-60 [-2.36]	60 [2.36]
CM _y	Center of mass, Y	Stowed in CSD	mm [in]	10 [0.39]	70 [2.76]	10 [0.39]	70 [2.76]	55 [2.17]	125 [4.92]	100 [3.94]	180 [7.09]
CM _z	Center of mass, Z	Stowed in CSD	mm [in]	133 [5.24]	233 [9.17]	133 [5.24]	233 [9.17]	133 [5.24]	233 [9.17]	133 [5.24]	233 [9.17]
Height	Maximum payload depth, +Y dimension		mm [in]	0	109.7 [4.319]	0	109.7 [4.319]	0	222.8 [8.771]	0	332.8 [13.102]
Width	Maximum payload width from origin, ±X dimension		mm [in]	0	56.55 [2.226]	0	119.7 [4.713]	0	119.7 [4.713]	0	176.25 [6.939]
Tab Width	±X dimension		mm [in]	112.7 [4.437]	113.1 [4.453]	239.0 [9.409]	239.4 [9.425]	239.0 [9.409]	239.4 [9.425]	352.1 [13.862]	352.5 [13.878]
Tab Length	+Z dimension		mm [in]	361 [14.21]	366 [14.41]	361 [14.21]	366 [14.41]	361 [14.21]	366 [14.41]	361 [14.21]	366 [14.41]
EP _y	Ejection plate contact zone, +Y dimension from origin		mm [in]	-	100 [3.94]	-	100 [3.94]	-	213 [8.39]	-	326 [12.84]
DC_X1	Deployable contact zone with CSD, ±X face near +Y face		mm [in]	91.4 [3.598]	-	91.4 [3.598]	-	204.5 [8.051]	-	317.6 [12.504]	-
DC_X2	Deployable contact zone with CSD, ±X face near -Y face		mm [in]	-	20.3 [0.799]	-	20.3 [0.799]	-	20.3 [0.799]	-	20.3 [0.799]
DC_+Y	Deployable contact zone with CSD, +Y face (1)		mm [in]	43.85 [1.726]	-	107.0 [4.213]	-	107.0 [4.213]	-	163.55 [6.439]	-
DC_-Y	Deployable contact zone with CSD, -Y face (1)		mm [in]	31.2 [1.228]	-	94.3 [3.713]	-	94.3 [3.713]	-	150.9 [5.941]	-
F _{DS}	Force from deployment switches, summated, Z axis	When contacting CSD ejection plate	N	0	5.0	0	5.0	0	5.0	0	5.0
D _{DS}	Payload separation from ejection plate necessary to change deployment switch state, Z axis		mm [in]	1.3 [0.05]	12.7 [0.50]	1.3 [0.05]	12.7 [0.50]	1.3 [0.05]	12.7 [0.50]	1.3 [0.05]	12.7 [0.50]
F _{FD}	Friction force deployables impart on CSD walls during ejection	summated (all 4 sides)	N	0	2.0	0	2.0	0	2.0	0	4.0
F _{ND}	Normal force deployables impart on CSD walls during ejection	per bearing contact	N	0	9.0	0	9.0	0	9.0	0	9.0
TML	Total Mass Loss	Per ASTM E 595-77/84/90	%	0	1.0	0	1.0	0	1.0	0	1.0
CVCM	Collected Volatile Condensable Material	Per ASTM E 595-77/84/90	%	0	0.1	0	0.1	0	0.1	0	0.1
DP	CSD de-pressurization rate	During launch	psi/ sec	0	0.5	0	0.5	0	0.5	0	0.5
D _x	Location of optional separation electrical connector, +X dimension		mm [in]	40.80 [1.606]	41.06 [1.616]	103.96 [4.093]	104.22 [4.103]	103.96 [4.093]	104.22 [4.103]	160.50 [6.319]	160.76 [6.329]

(1) Some contact zones are not present on the 3U. Refer to Figure 5 for locations.

COMMON REQUIREMENTS

1. Tabs shall be 100% continuous 7075-T7 aluminum alloy. Other aluminum alloys of equivalent or stronger yield strength may be substituted. Tabs shall also be Hard Anodized per MIL-A-8625, Type III, Class 1. All dimensions apply AFTER hard anodize. Note that Anodize thickness refers to the total thickness (i.e. 0.001 total thickness = 0.0005 penetration + 0.0005 build-up). Max surface roughness of Tabs = 0.8 μ m Ra.
2. Tabs shall run the entire length of the payload. No portion of the payload may extend beyond the tabs in the +Z or –Z directions.
3. Dimensions and tolerances in Figure 5 shall be maintained under all temperatures. Consider CTE warping of tabs if structure is not aluminum.
4. The structure comprising the –Z face (face that contacts CSD ejection plate) may be a uniform surface or consist of discrete contact points. The discrete contact points shall be located such that they envelope the payload's C.M. and the three deployment switches.
5. Deployment (inhibit) switches shall reside in specified zone on -Z face. Switches will activate upon contact with CSD ejection plate.
6. Safe/Arm plug, if necessary, shall reside in specified zone on +Z (preferred), +X, or -X face.
7. All non-constrained deployables shall be hinged near the +Z face to minimize snagging hazards during ejection. The deployables shall be tested with the CSD prior to flight.
8. -Z face of payload shall withstand a 400 N force imparted by CSD ejection plate during launch due to vibration.
9. If electrical grounding to the CSD is desired, the Separation Electrical Connector (In-Flight Disconnect) must be used. See Ref. 3.
10. The two tabs and the structure that contacts the CSD ejection plate on the –Z face are the only required features of the payload. The rest of the payload may be any shape that fits within the max dynamic envelope.
11. No debris shall be generated that will inhibit separation.
12. A fit check with a CSD shall be performed at the earliest possible time.

ELECTRICAL SCHEMATIC

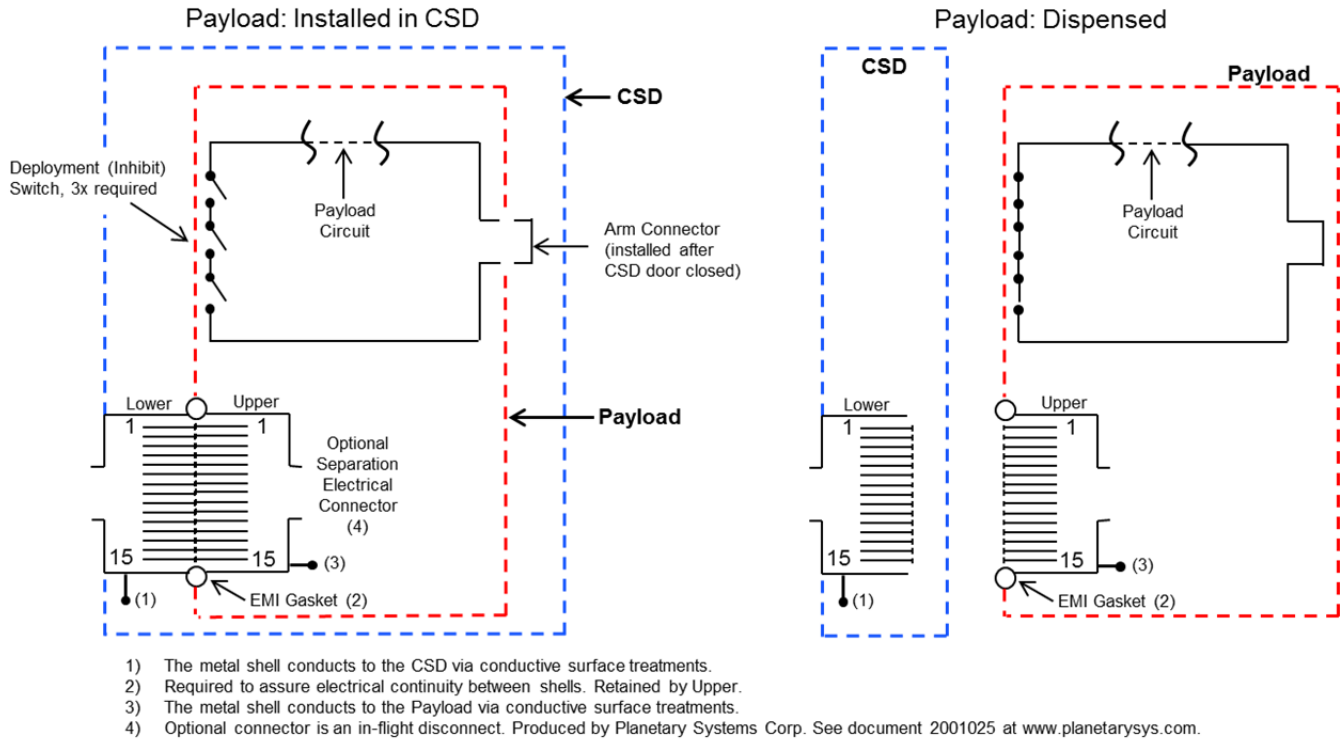


Figure 3: Electrical Schematic

DIMENSIONS

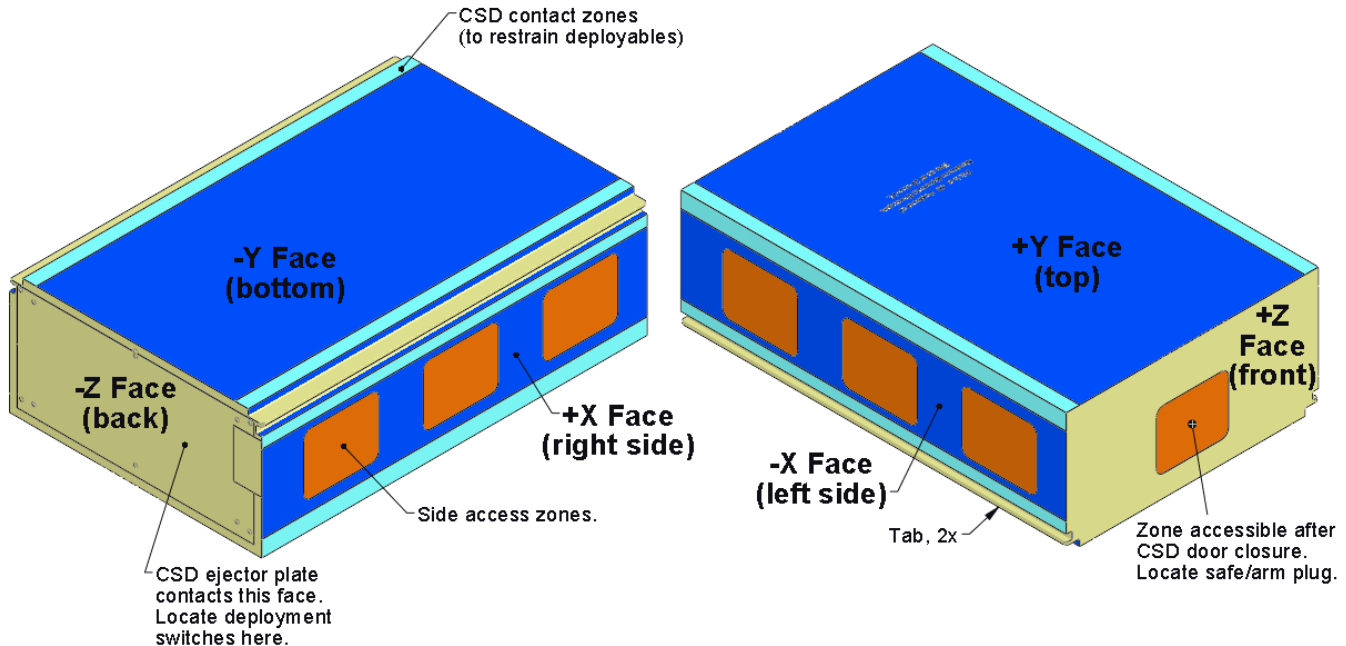


Figure 4: Payload Features (6U Shown)

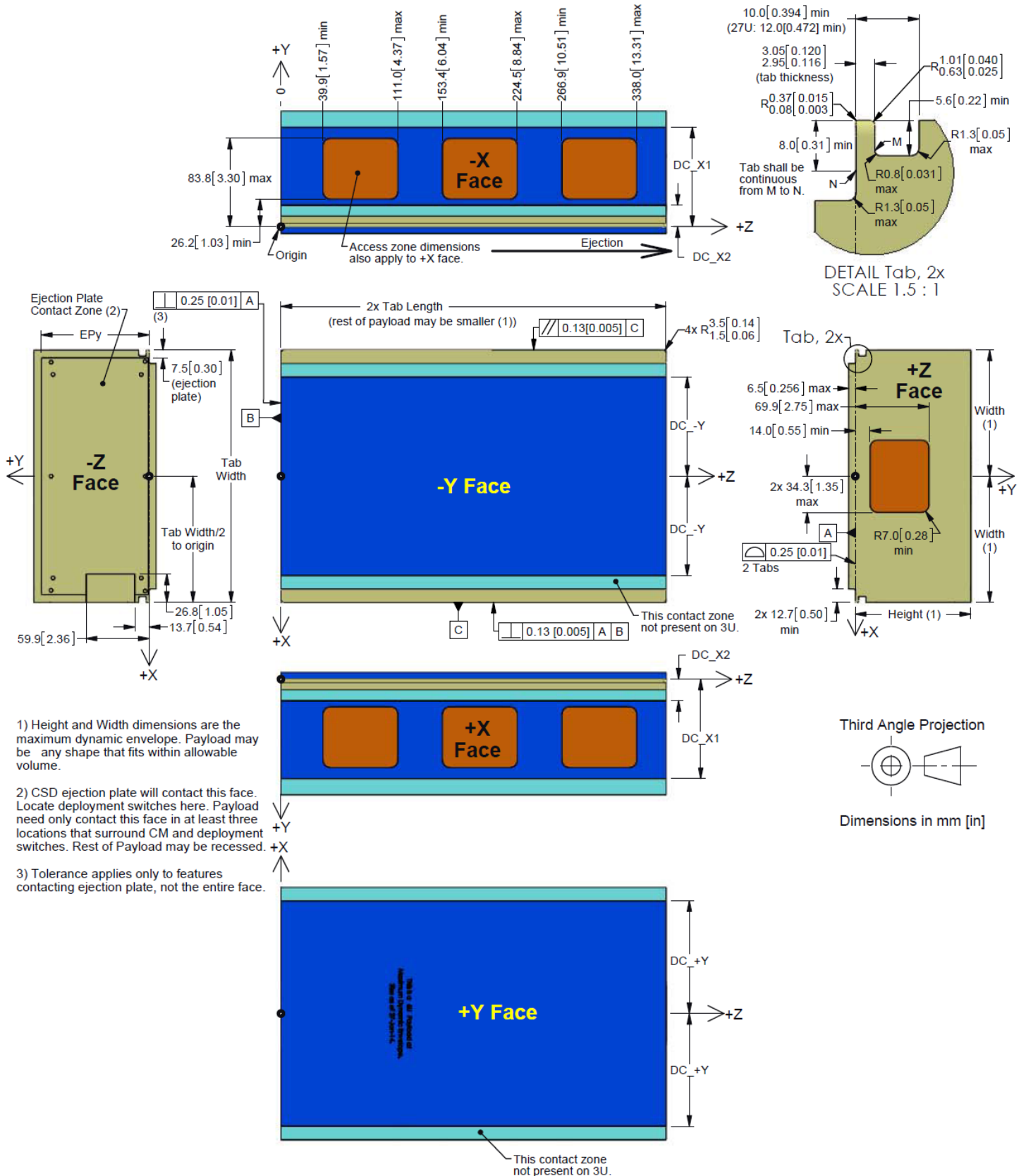


Figure 5: Payload Dimensions

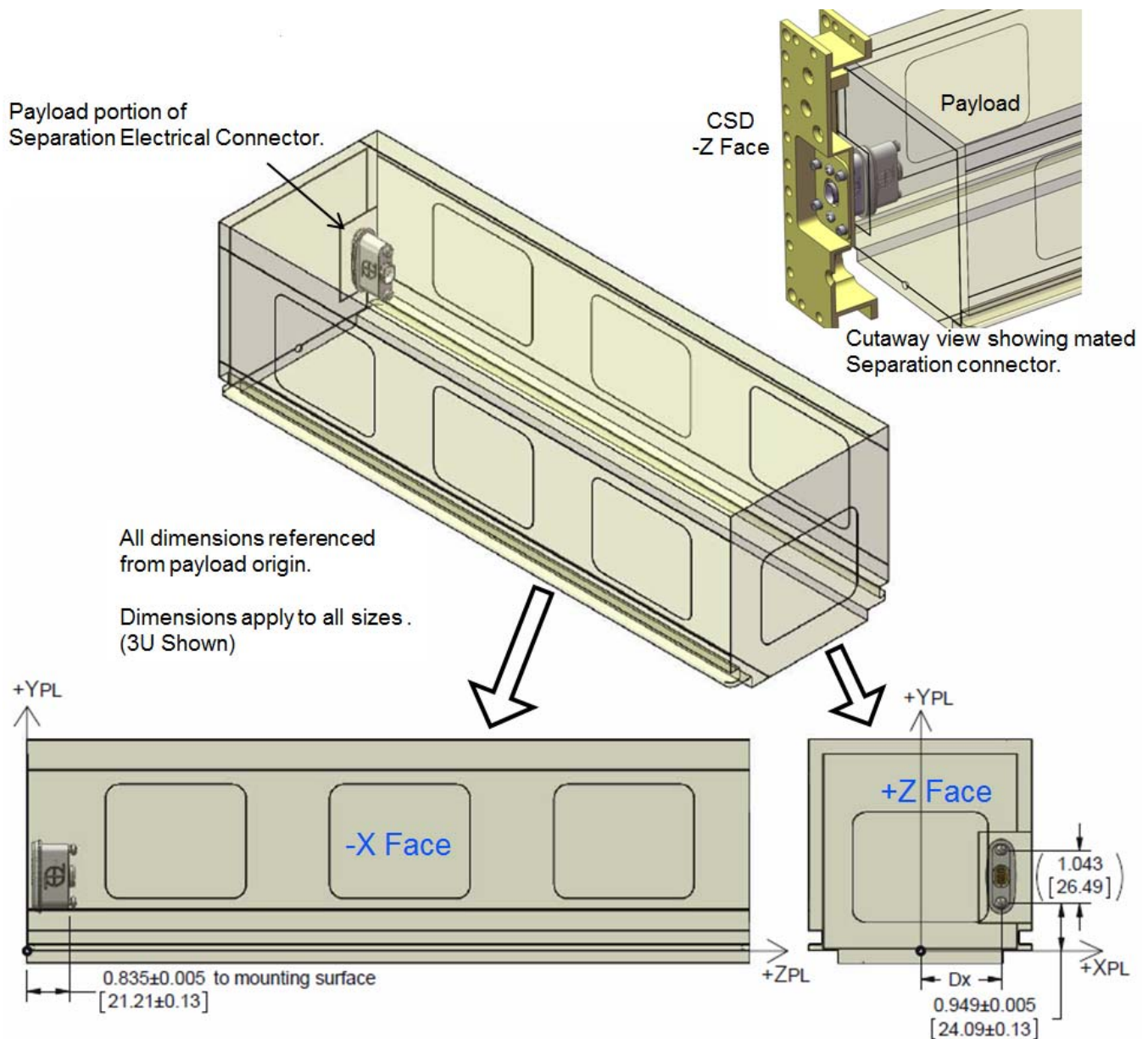
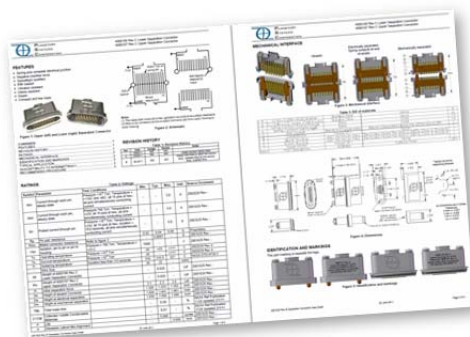


Figure 6: Location of Optional Separation Electrical Connector (In-Flight Disconnect)

For more information on the Separation Electrical Connector see PSC document 2001025 Separation Connector Data Sheet. Ref. 3. Also see section *Separation Electrical Connector Attachment*.



DISCRETE PAYLOADS

Multi-piece payloads are allowed provided they meet the following requirements.

- 1) Total length of all pieces: must comply with 'Tab Length' in Parameters Section.
- 2) Minimum allowable tab length of a single piece: 50mm [2.0 in].
- 3) Minimum tab gap between adjoining pieces (Z direction): 0.5mm [0.02 in].
- 4) Tab thickness of the extreme fore and aft pieces: equal to or greater than the adjoining piece.

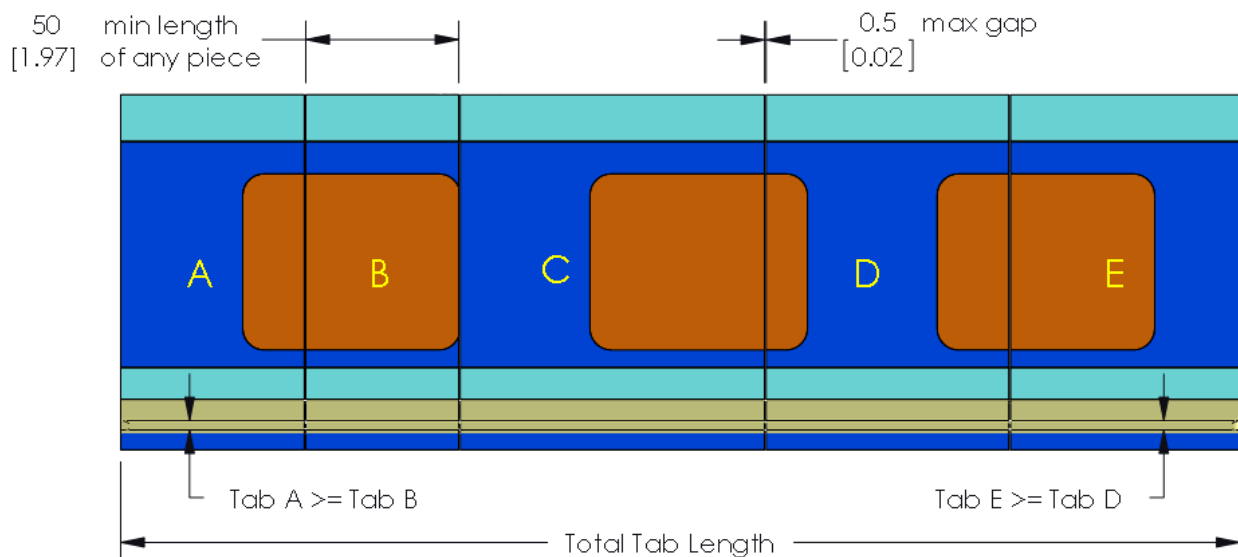


Figure 7: Generic Multi-Piece Payload (dimensions mm [in])

See Figure 24 and Figure 25 for examples of discrete payloads.

DESIGNS WITH TABS REMOVED

A payload can be designed with large tab gaps if necessary. This requires a CSD customization. Contact the CSD manufacturer if non-continuous tabs are desired.

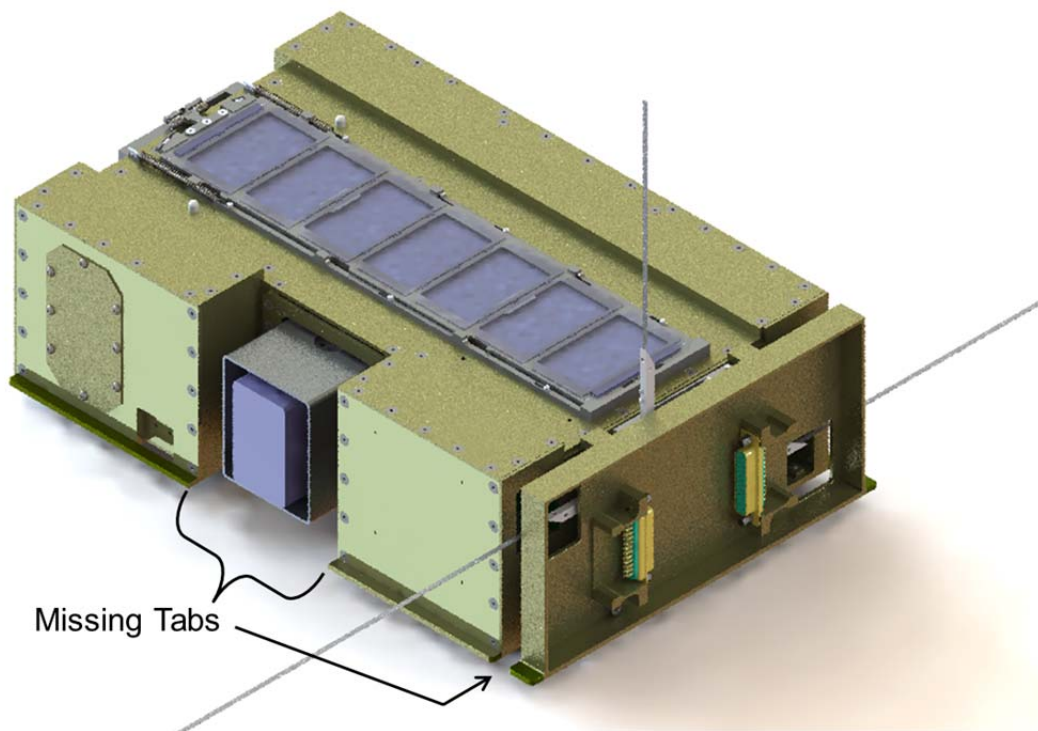


Figure 8: 6U Payload with Non-Continuous Tabs

BENEFIT OF TABS

Preloading the payload to the CSD by virtue of clamping the tabs creates a stiff invariant load path. This allows for accurate dynamic modeling to predict responses in anticipation of vibratory testing and space flight. Confidently predicting response is critical for aerospace structures and sensitive components. A payload that can move inside its dispenser is unmodelable and therefore the loading of sensitive components can not be predicted.

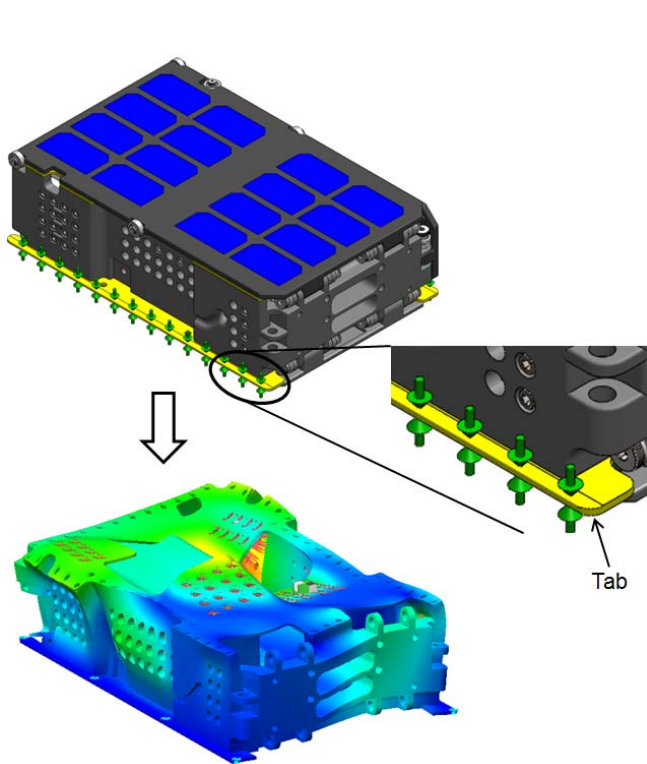
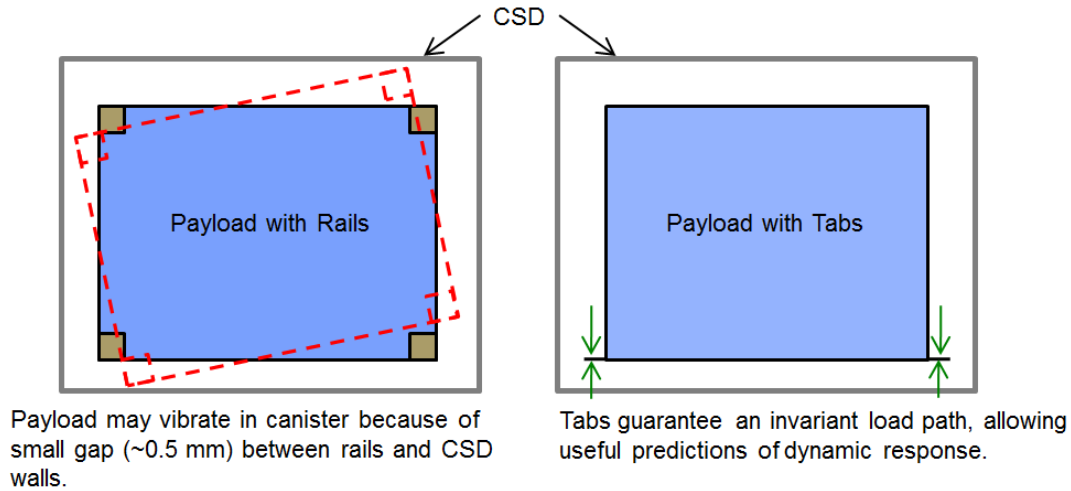


Figure 10: Prediction of 6U Dynamic Response

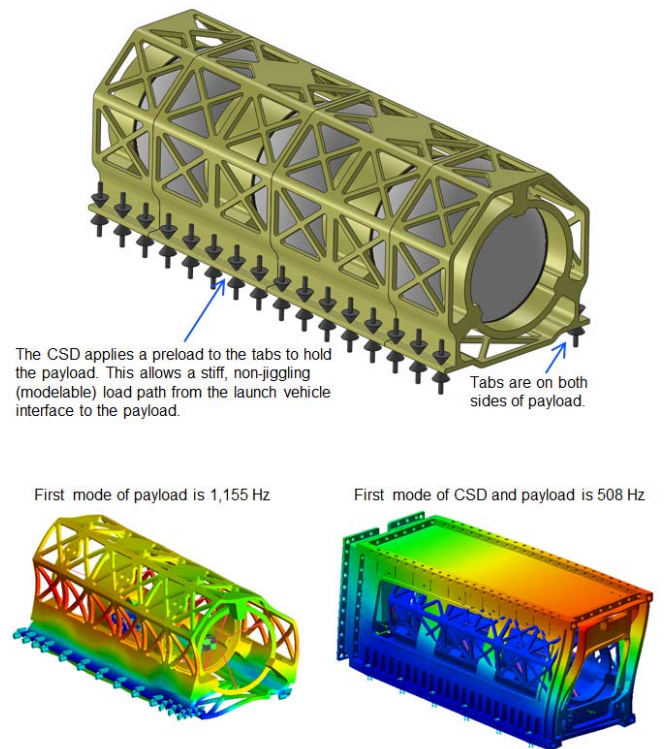
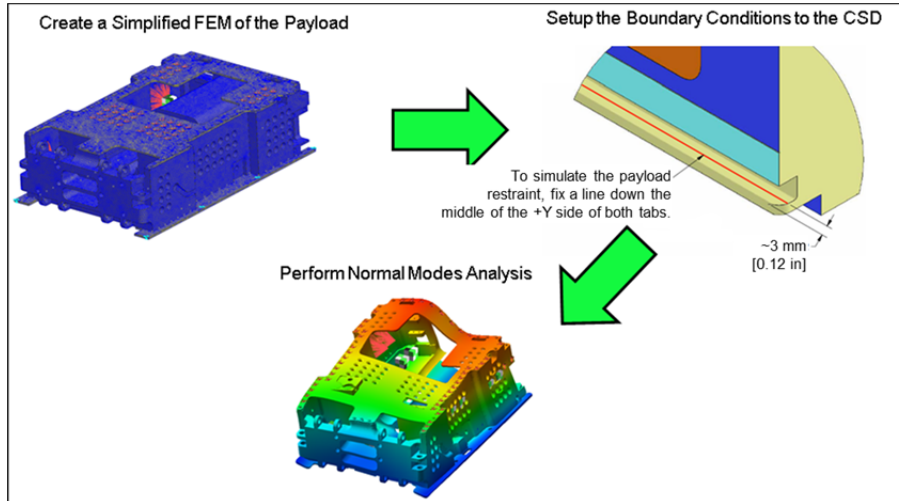


Figure 11: Prediction of 3U Dynamic Response

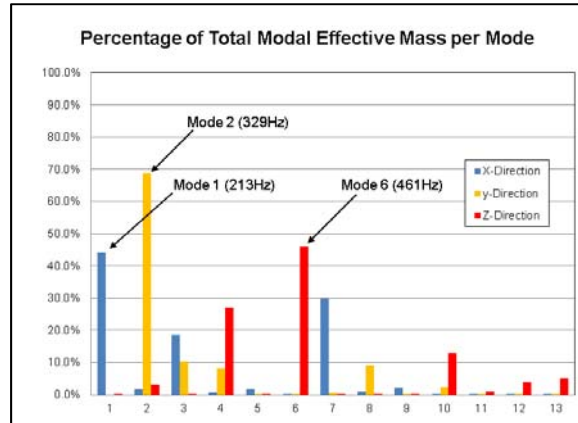
PREDICTING DESIGN LIMIT LOADS

The maximum structural loading typically results from the dynamic response during random vibration testing and/or shock testing. These loads are dependent on the mass, stiffness, and dampening properties unique to each payload. The method below provides a rudimentary means of predicting these loads.

- 1) Create a simplified model of the payload consisting of the primary structure and significant components for a Normal Modes Analysis from 20-2,000Hz.



- 2) Identify the dominant resonant frequencies and mode shapes for each orthogonal direction (X, Y, Z). These modes can be identified as having the highest percentage of Modal Effective Mass relative to all modes modeled within the frequency bandwidth stated above.



- 3) The response for a random vibration profile can be predicted by using the Miles Relation shown below:

$$Grms = \sqrt{0.5 * \pi * f_n * Q * ASD}$$

Grms [g] = 1σ acceleration response

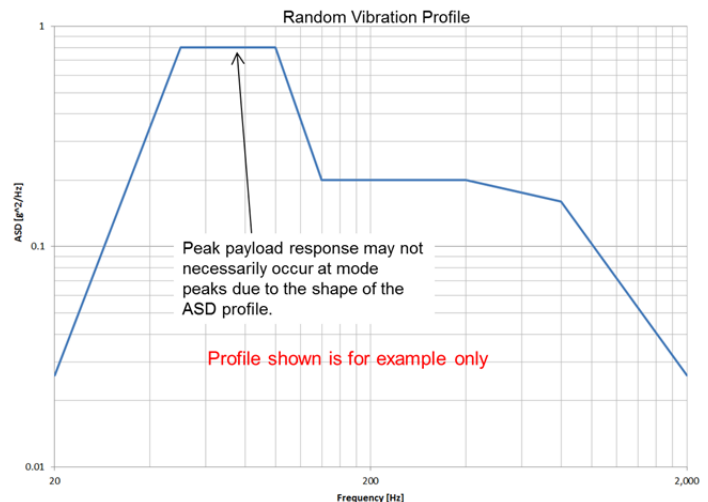
f_n [Hz] = natural frequency (frequency of selected mode)

Q [-] = $\frac{1}{2*\zeta}$ = quality factor (use 10 as an estimate if unsure)

ζ [-] = critical dampening

ASD [g^2/Hz] = input acceleration spectral density at the desired frequency f_n

Assume the peak response is $3\sigma = 3*Grms$



All payloads behave uniquely. The figure below shows two payload mockups of the same mass with very different responses. The mockup on the left has numerous discrete masses and bolted joints. There are many modes and the dampening is typical of many payloads. The mockup on the right consists of a few very stiff aluminum plates. There is one very dominate mode over a wide frequency range that results in significant loading.

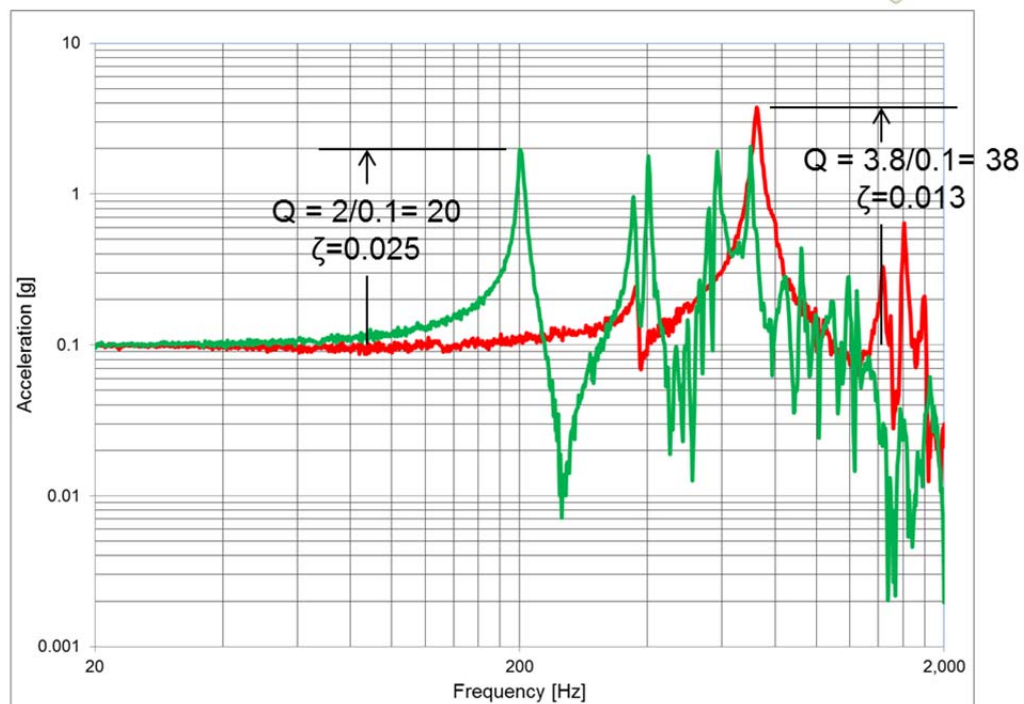
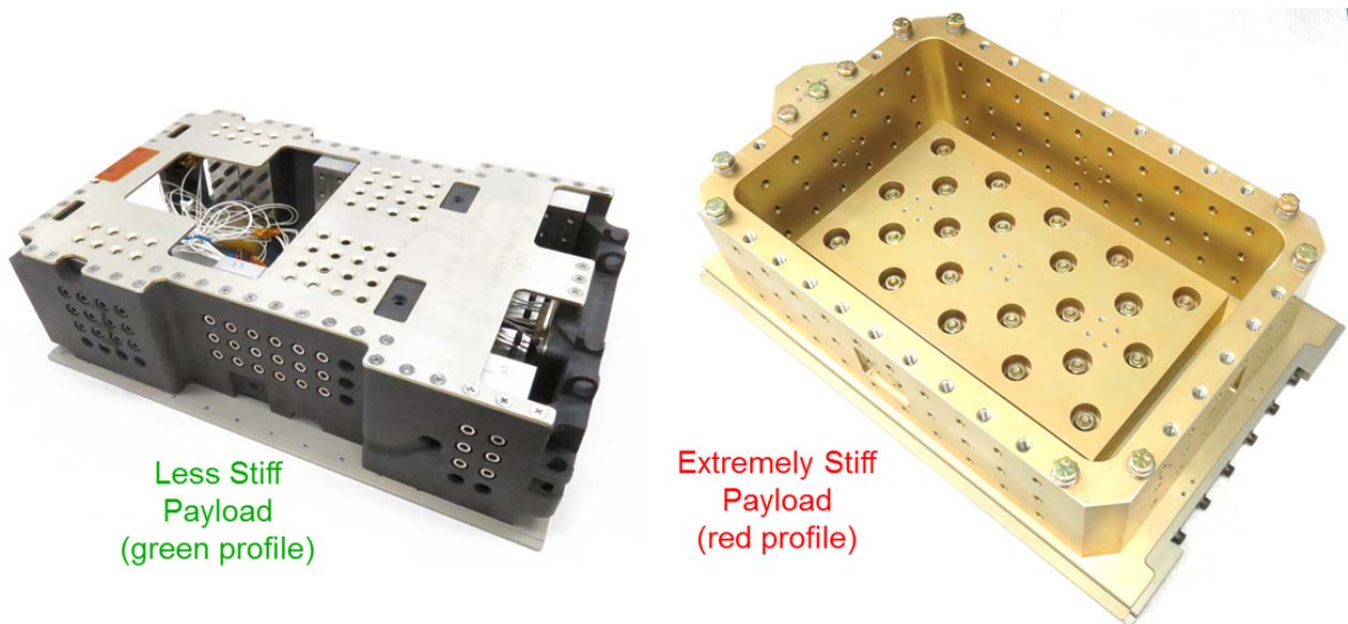


Figure 12: Comparison of Payload Responses

The response of the payload will significantly affect the loading on critical parts like reaction wheel bearings, complex mechanisms and optics. Ensuring a consistent load path from the launch vehicle to the payload (i.e. preloading) is the only way to accurately predict the loading from thermal, vibration and shock.

TAB MANUFACTURING

Designing and manufacturing tabs that meet the requirements of this document are critical for successful integration and deployment of a payload. As the interface to the CSD, the tabs shall be designed, dimensioned, manufactured, and inspected with care.

Production Drawings

The figure below shows an example production drawing of a plate with tabs. Some of the tolerances are tighter than this specification requires. Also, the tabs do not have to be on a discrete plate as shown. They can be discrete bolt-on features or machined into a more intricate structure.

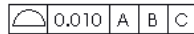
NOTES

1. Material: Al-Aly 7075-T7351 per AMS-QQ-A-250/12 or AMS 407B.
2. This is a Limited Dimension Drawing, governed by the following specifications.

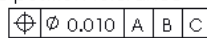
Basic: Features considered basic shall be defined in ANSI Y14.5M-1994.

Angles: All angles shall be considered basic unless otherwise noted.

Profile Tolerances: Unless otherwise noted, the profile tolerances shall be as follows (where A, B, and C are the primary, secondary, and tertiary datums respectively):



True Position Tolerance: Unless otherwise noted, the true position tolerance for features shall be as follows:



Surface roughness: Unless otherwise specified, MAX surface roughness shall be: $\sqrt{32}$

Internal radii: Internal machined corners shown as sharp edges may have R0.010 MAX.

External radii: External machined corners shown as sharp edges may have R0.010 MAX.

Holes: All holes shall have a diameter tolerance of ± 0.003 .

4. De-burr and break sharp edges.
5. All Dimensions apply after surface finish.
6. Surface Finish: Hard Anodize per MIL-A-8625, Type III, Class I, 0.0010 Thick (0.0005 penetration +0.0005 build-up = 0.001 total thickness)
No masking.
Do not contact precision tabs in Detail L during Plating.

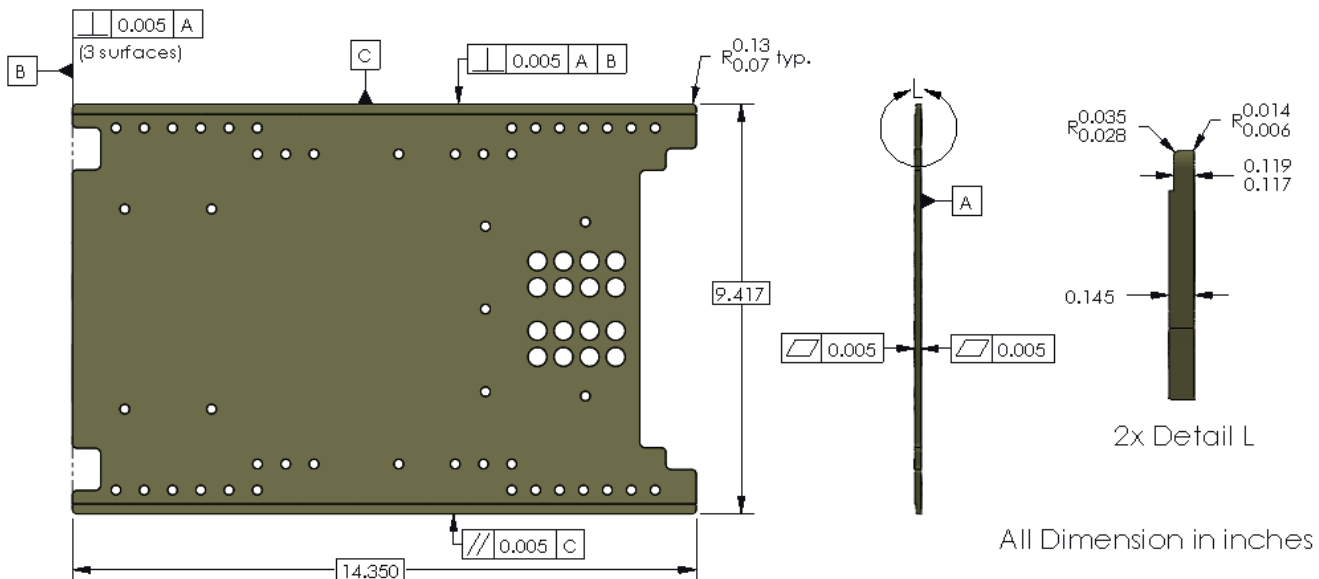
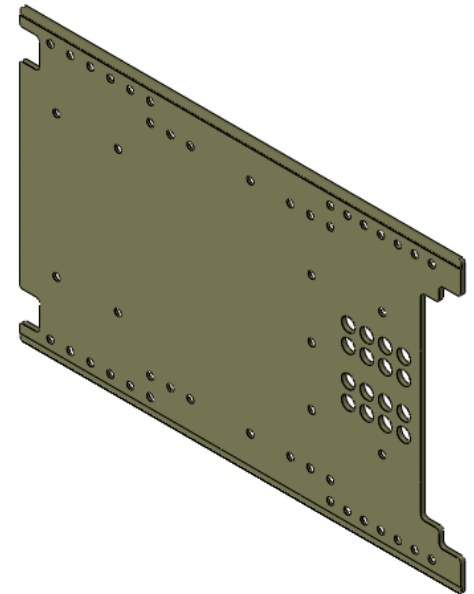


Figure 13: An Example Tab Production Drawing

Inspection

Measure the tab thickness using a micrometer as follows. A digital caliper lacks the required accuracy.



Figure 14: Measuring Tab Thickness with Micrometer

- 1) Select a micrometer with an accuracy and resolution of 0.00005 inches (0.001 mm).
- 2) Ensure micrometer surfaces and tabs are clean.
- 3) Use a gauge block to verify micrometer accuracy and operator technique.
- 4) Mark increments at every inch along tab length.
- 5) Take minimum three measurements at each location to ensure repeatability.
- 6) Record and plot measurements.
- 7) All measurements shall be within tolerance. The figure below shows an example of tabs that are NOT acceptable.

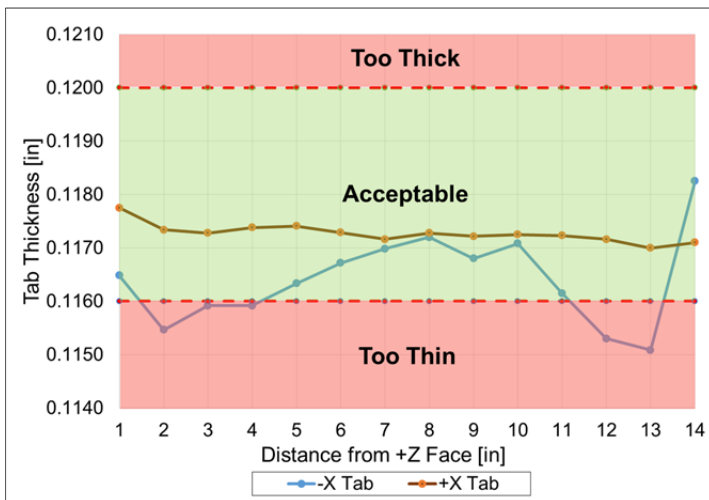


Figure 15: Tab Thickness Measurement

Also verify the following critical aspects of the tabs.

- 1) All edge fillets are in tolerance. See Detail L in Figure 13 for an example.
- 2) Hard anodize is continuous along entire tab surface (top, bottom and sides). Location defined as between M-N in Detail Tab in Figure 5.

After the payload structure is assembled the tabs shall remain flat per Figure 5. Place the payload on a verified flat surface (granite surface plates are ideal). A 0.010 inch thick feeler gage or gage pin shall not fit under any portion of the tab. See figure below.

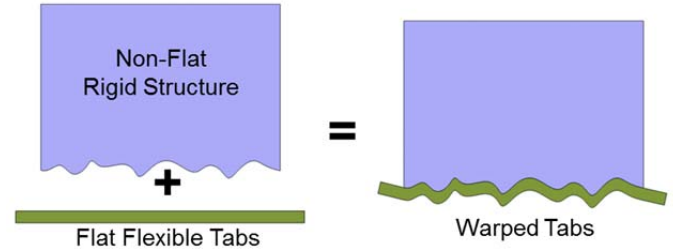


Figure 16: Example of Structure Warping Tabs

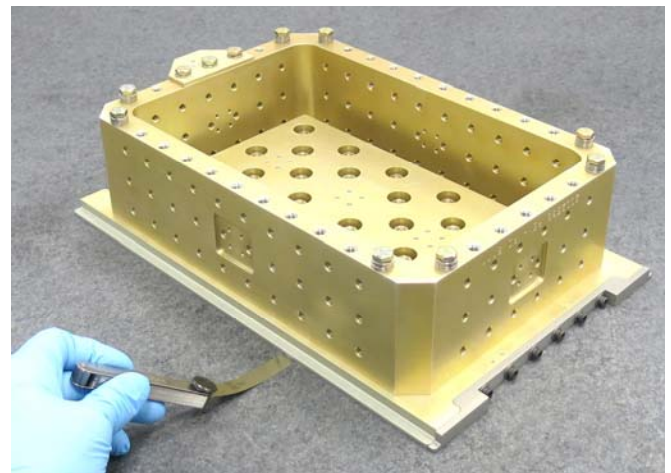


Figure 17: Verifying Assembled Flatness

CSD CONSTRAINED DEPLOYABLES

The payload may use the CSD to constrain deployables in designated areas as defined in the Parameters and Dimensions sections. At these designated contact zones the CSD interior surface shall be 1.3mm [0.05 in] from the maximum allowable dynamic envelope of the payload defined as 'Width' and 'Height'. Only the portion of the payload directly contacting the CSD Walls (bearing, etc.) may exceed the payload dynamic envelope.

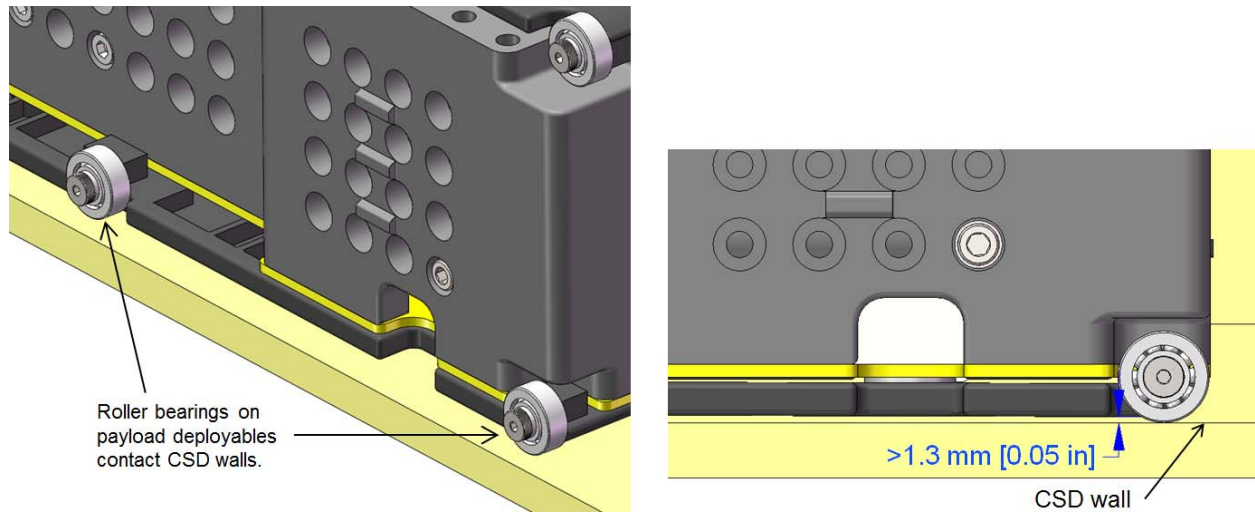


Figure 18: Deployable Contact with CSD

Deployables Design Notes:

- Ensure bearing spacing and panel stiffness are sufficient to prevent any portion of the panel from rubbing on the dispenser as the payload ejects.
- Deployables should have features to react shear loading at end opposite hinge. This prevents excessive loading on the hinge and deflection at the end of the deployable during launch.
- The deployable panels shall be sufficiently preloaded against the payload structure to minimize rattling during launch. This can be accomplished by incorporating a leaf spring, spring plunger, etc.
- Account for tolerance build-up in the deployable preload system. By necessity, the dispenser width will be greater than the tab width. During payload installation there will be up to 0.5mm [0.020 inches] of play relative to nominal in the +X or -X positioning of the payload. Therefore the +X or -X contact walls of the dispenser may be 0.8 to 1.8 mm [0.03 to 0.07 inches] from the payload's nominal max dynamic envelope.

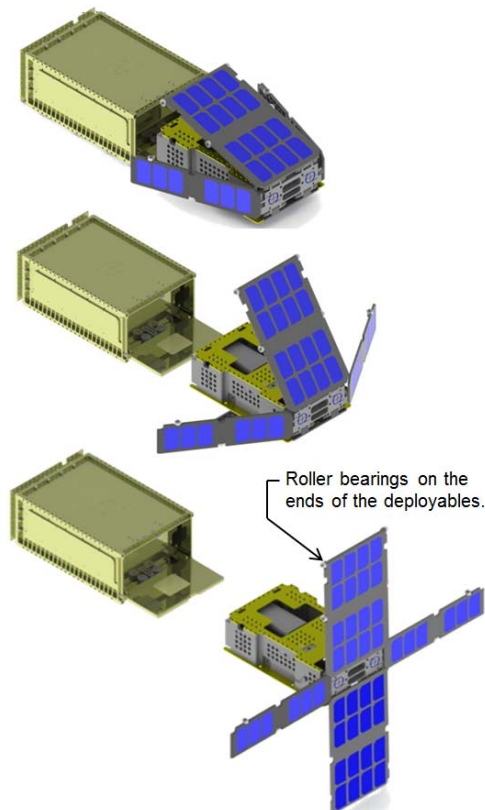


Figure 19: Payload Dispensing from CSD

PAYLOAD VOLUME

The allowable volume of the payloads is larger than existing CubeSats.

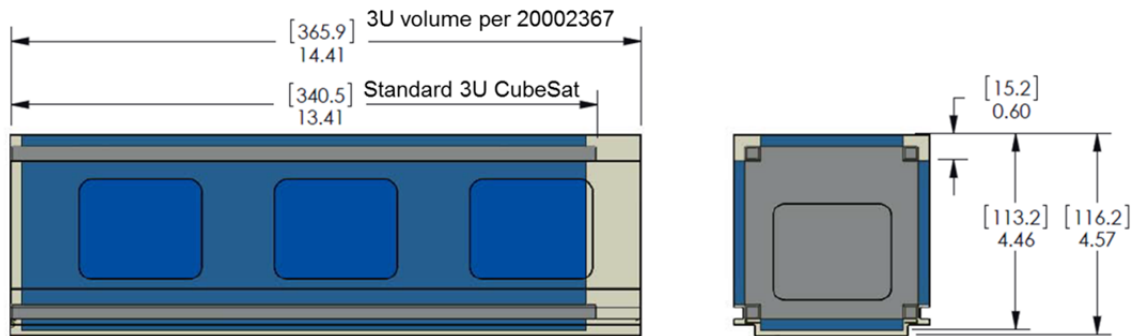


Figure 20: Comparison of 3U Payload Volumes. This specification allows 15% more payload volume.

Allowable Volume
PSC: 615 in³
Others: 564 in³

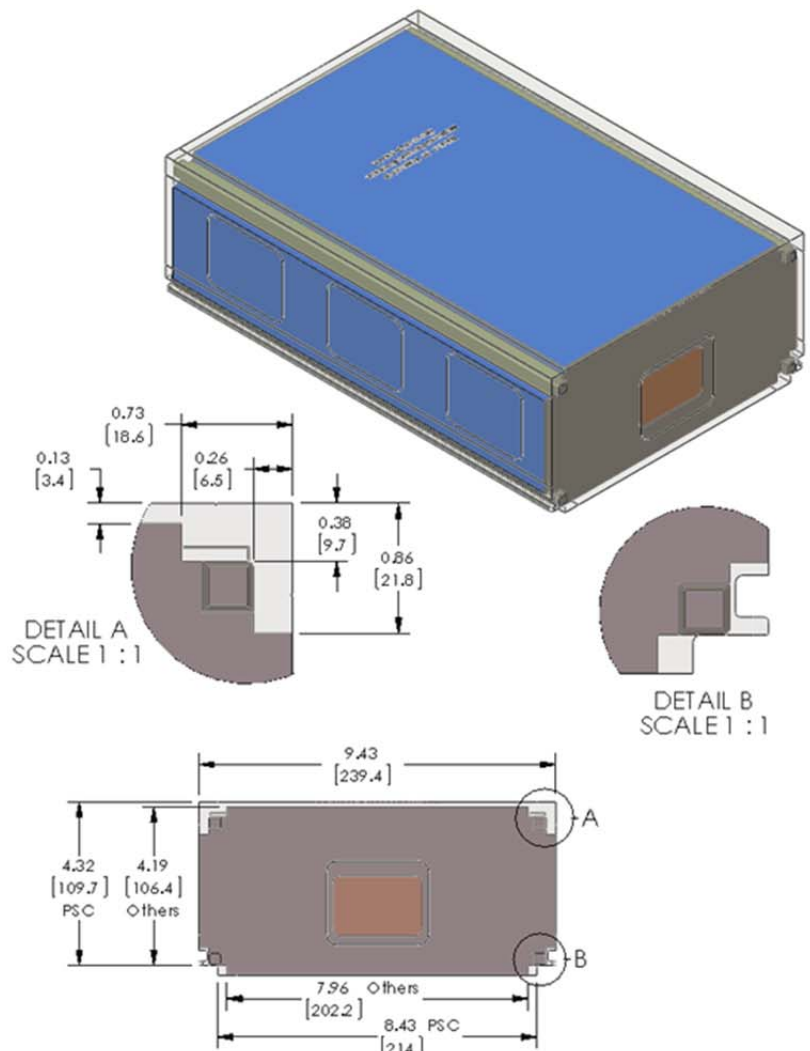
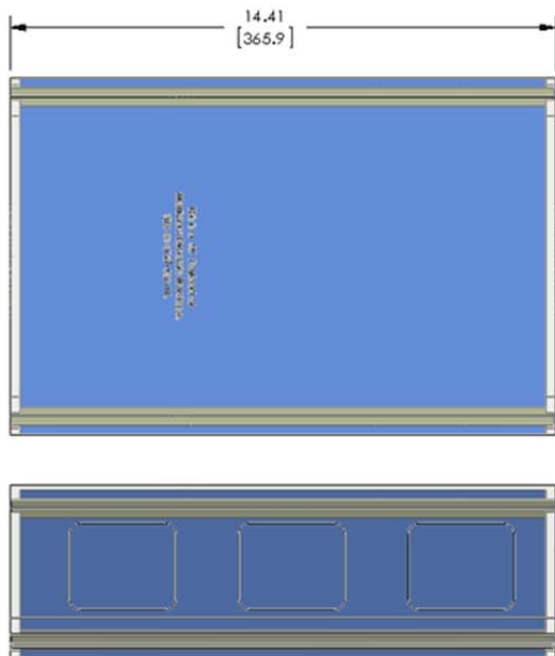


Figure 21: Comparison of 6U Payload Volumes. This specification allows 9% more payload volume.

TYPICAL APPLICATIONS

An existing CubeSat with 4 corner rails can easily comply with this specification by fastening on tabs.

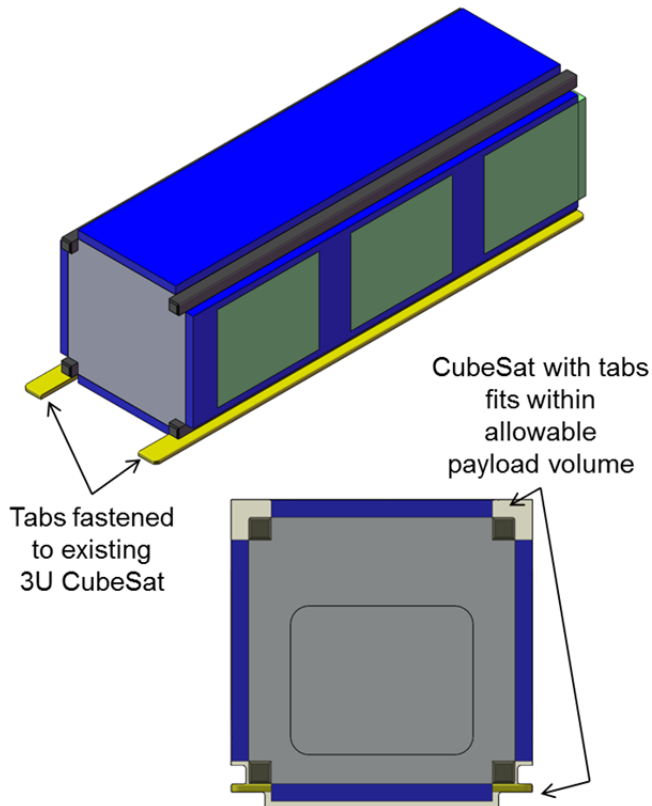


Figure 22: 3U CubeSat Tab Conversion

The payload need not occupy the entire volume as long as the tabs are present.

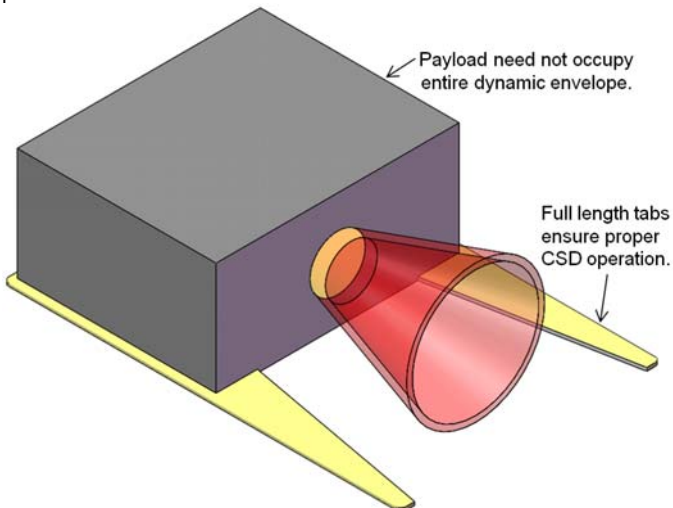


Figure 23: 6U Payload Example



Figure 24: POPACS, A Multi-Piece 3U Payload

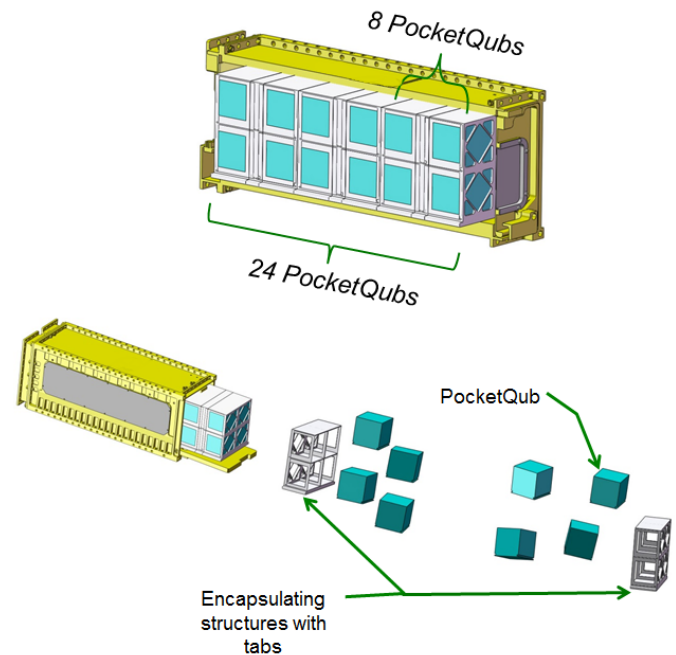


Figure 25: Encapsulating PocketQubs in a Tabbed Structure

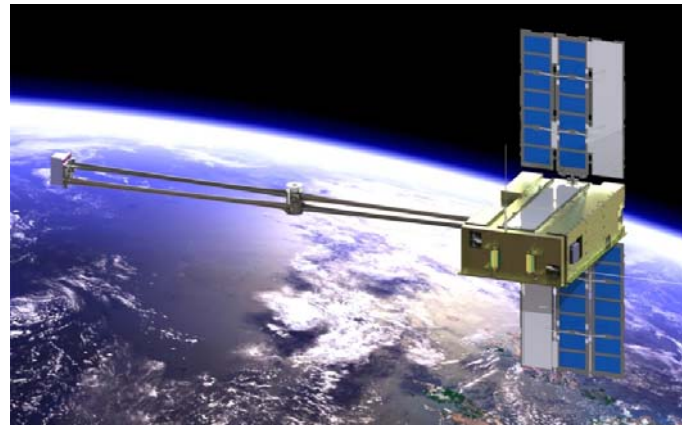


Figure 26: 6U Payload

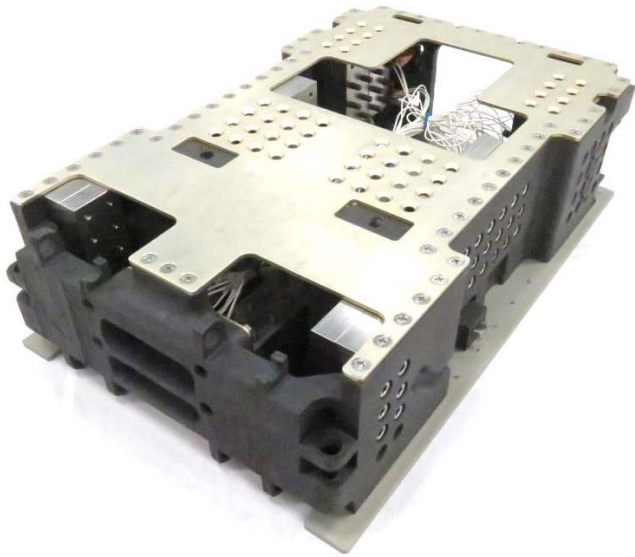


Figure 27: 3D Printed 6U Mockup Structure

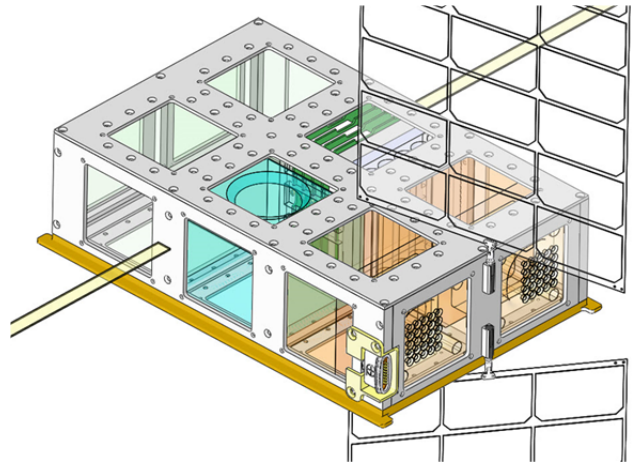


Figure 29: 6 X 1U Bus

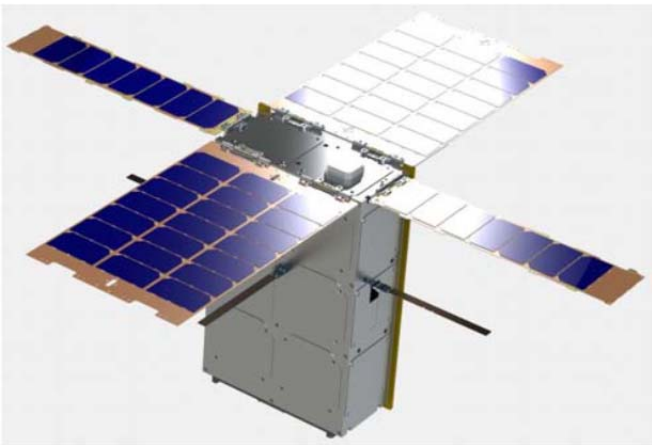


Figure 28: Pumpkin Inc.'s 6U SUPERNOVA Bus

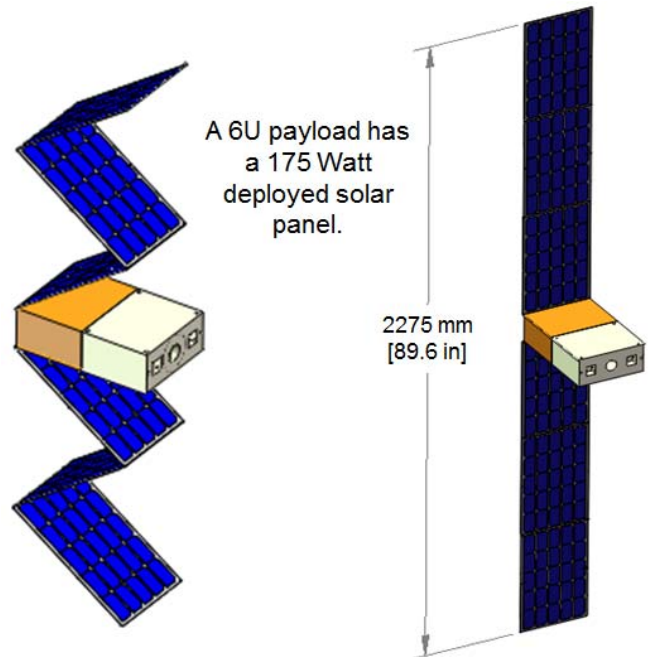


Figure 30: Solar Array Potential

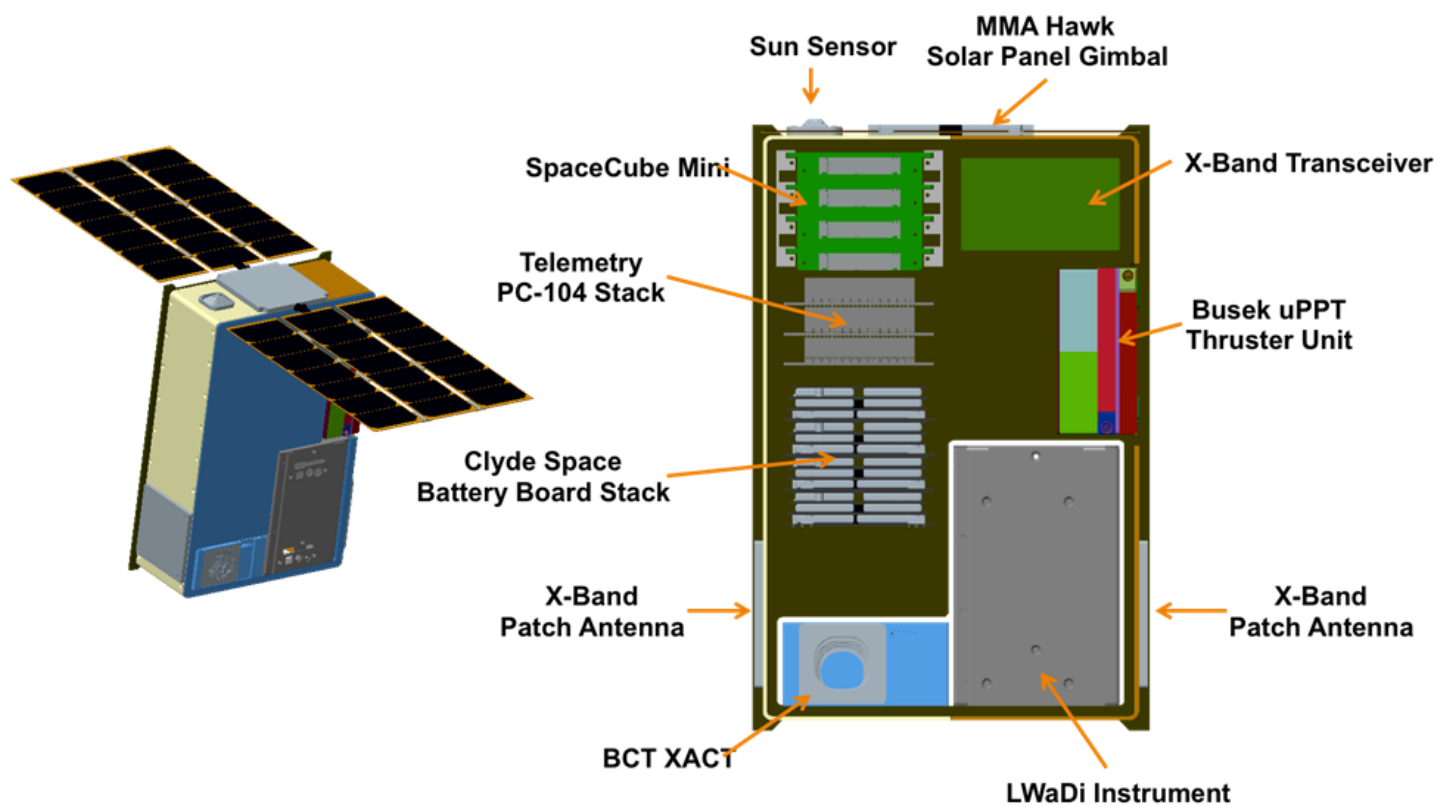


Figure 31: Lunar Water Distribution (LWADI), a 6U Interplanetary Spacecraft. Ref. 6.

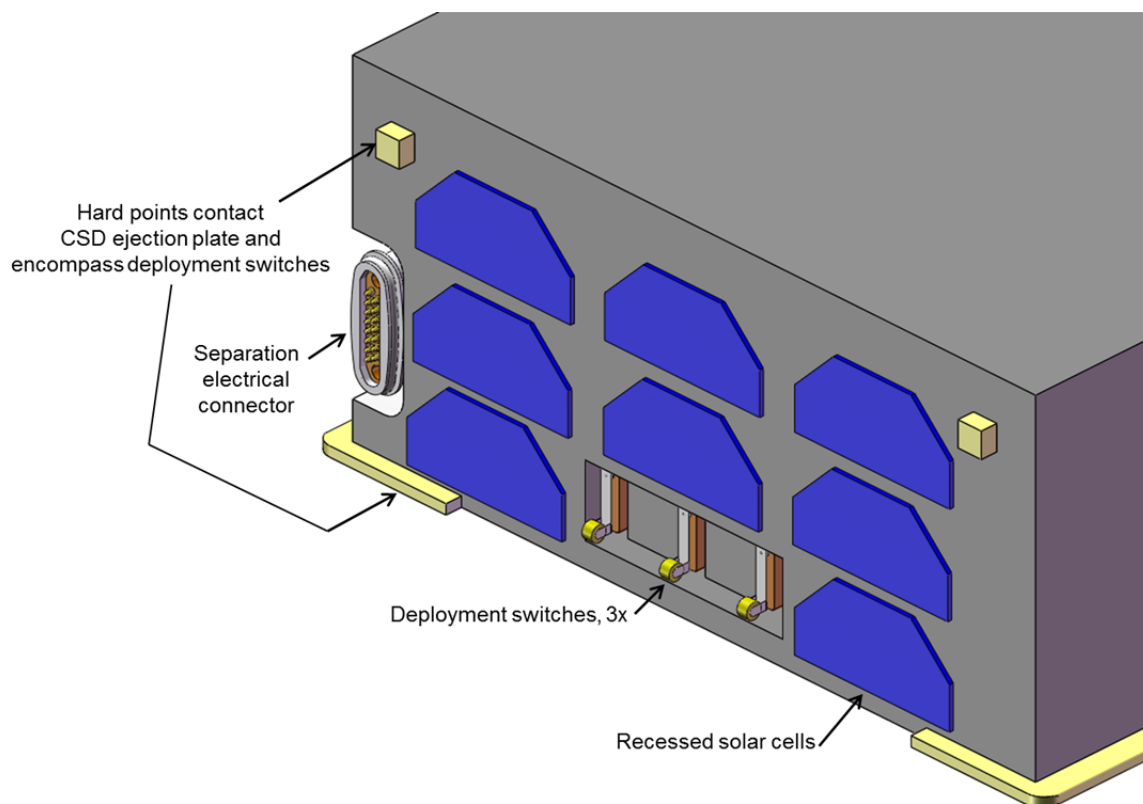


Figure 32: Example of -Z Face that Contacts Dispenser Ejection Plate

SEPARATION ELECTRICAL CONNECTOR ATTACHMENT

The figures below show a typical means of mounting the separation electrical connector. It only need be mounted via the flat face that contains the two #4 screws. Additional support around the side of the connector shell is unnecessary. An open cutout in the mounting bracket is beneficial as it allows the connector to be removed after the harness is wired.

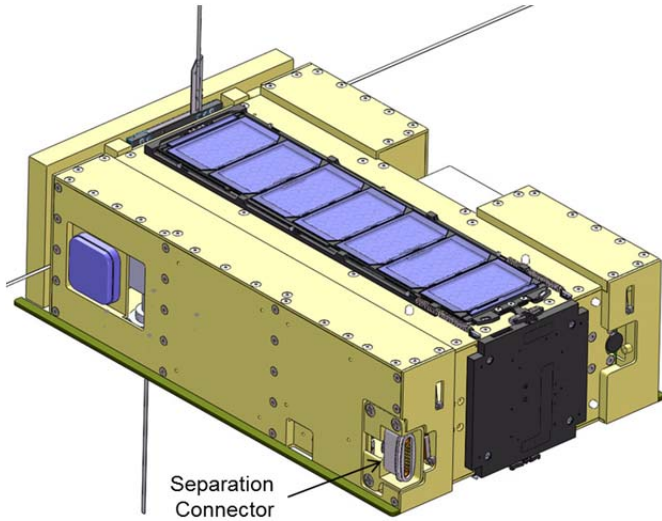


Figure 33: Separation Electrical Connector on Payload

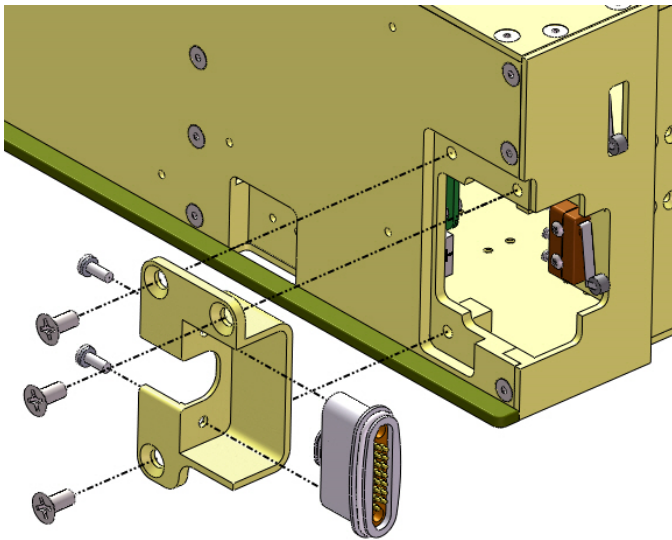
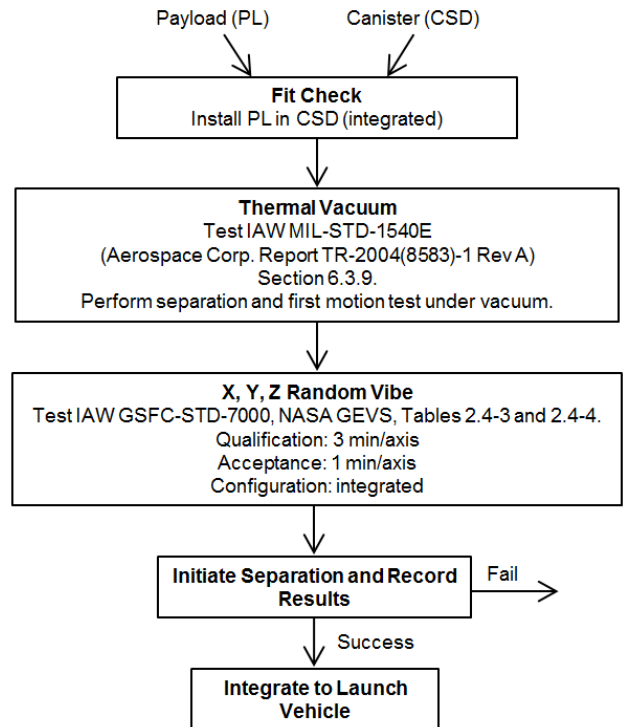


Figure 34: Separation Electrical Connector Mounting Example

RECOMMENDED TEST AND INTEGRATION

Test levels are for launch environment, not necessarily on-orbit.



TIPS AND CONSIDERATIONS

1. **Electrical Wiring:** Include the electrical harness in the CAD model. Ensure there are sufficient routing options, strain relief and clearances. Also, the harness can consume a significant portion of the allowable payload mass.
2. **Installation in CSD:** The payload may end up being installed vertically in the CSD (gravity in -Z). Add a removable handle on the +Z face to aide installation.
3. **CSD Ejection:** When possible, verify complete ejection of the payload from the CSD during testing.

CAD MODELS

Solid models of the payloads at their maximum dynamic envelope are available for download at www.planetarysys.com.

ADDITIONAL INFORMATION

Verify this is the latest revision of the specification by visiting www.planetarysys.com.

Please contact info@planetarysystemscorp.com with questions or comments. Feedback is welcome in order to realize the full potential of this technology.

REFERENCES

- 1 Hevner, Ryan; Holemans, Walter, "An Advanced Standard for CubeSats", Paper SSC11-II-3, 25th Annual AIAA/USU Conference on Small Satellites, Logan, UT, August 2011.
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- 4 CubeSat Design Specification, Rev 12, California Polytechnic State University, CA, Aug 2009.
- 5 Hevner, Ryan, "Lessons Learned Flight Validating an Innovative Canisterized Satellite Dispenser", Paper 978-1-4799-1622-1/14, 2014 IEEE Aerospace Conference, Big Sky, MT, January 2014.
- 6 Clark, Pamela, Holemans, Walter, Bradley, Wes, "Lunar Water Distribution (LWaDi)-- a 6U Lunar Orbiting spacecraft", 11th Annual Summer CubeSat Developers' Workshop, Logan, UT, 02-03 August 2014.

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REVISION HISTORY

Revision	Release Date	Created By	Reviewed By
-	25-Jul-2012	RH	WH
A	06-Aug-2013	RH	WH
B	21-Jul-2014	RH	WH

Changes from previous revision:

Section(s)	Changes
<i>Parameters</i>	-Depth: changed to Height - Height: increased 3mm on 3U-12U . -FND: changed from 'per wall' to 'per bearing' EL: deleted
<i>Common Requirements</i>	Added Note 3 about thermal warping.
<i>Dimensions</i>	Fig. 5: Changed Datums. Changed edge fillet radaii on tabs.
<i>Predicting Design Limit Loads</i>	Added example payloads and their response profiles.
<i>CSD Constrained Deployables</i>	Added design note details.
<i>Typical Applications</i>	Added numerous figures.
<i>Tips and Considerations</i>	Deleted machining tolerance note.
<i>Acknowledgements</i>	Renamed from <i>Authors</i> . Removed PSC names. Added people.
<i>Features & Benefits, Discrete Payloads, Designs with Tabs Removed, Tab Manufacturing, Payload Volume, References</i>	Added.
<i>Anticipated Improvements</i>	Deleted.