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An Advanced Standard for CubeSats

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ABSTRACT

It is critical for cost effective growth of CubeSats and other canisterized satellites to standardize a specification for payloads larger than those encapsulated and governed by the existing and highly successful 3U Poly Picosatellite Orbital Deployer (P-POD) standard. The US government wants larger CubeSats than the existing P-POD can dispense. Based on extensive consultation with Dr. Jordi Puig-Suari, Dr. Bob Twiggs, several individuals at Space Test Program (STP), Air Force Research Lab (AFRL), and many university CubeSat teams an advanced CubeSat and its dispenser specification is presented. The new specification currently governs CubeSats larger than the 3U size. This includes a 6U (12 Kg, 12 x 24 x 36 cm), 12U (24 Kg, 23 x 24 x 36 cm) and 27U (54Kg, 34 x 35 x 36 cm).

Canisterized Satellite Dispensers (CSDs) are boxes that small payloads (CubeSats) are housed in during launch and dispensed from once in space. These dispensers reduce the risk that small secondary or tertiary payloads in the dispenser can damage the primary or be damaged by the primary.

Standardization of the electrical and mechanical interfaces allows satellite builders and launch service providers to minimize the cost of integration to a launch vehicle because it greatly reduces the cost and time associated with non-recurring engineering. Further, standardization allows the greatest number of competitors to offer competing products so the end user has many low cost choices.

INTRODUCTION

CubeSats have been extremely successful in easing access to space. The small size and encapsulation maximize launch opportunities and allow the payload designer liberties with materials and manufacturing techniques. It also enables the launch vehicle (LV) to utilize existing capability with minimal risk to the primary payload. Expanding upon the success of the 1U and 3U, a larger family of payloads will enable even greater scientific and military capabilities. These 6U, 12 and 27U payloads feature advanced technologies that streamline integration and ensure mission success. A 6U payload is shown deploying from its canister in Figure 1. These new sizes fill the existing mass and volume gap between 3U CubeSats and traditional separation system restrained secondary payloads (ESPA and similar). See Figure 2

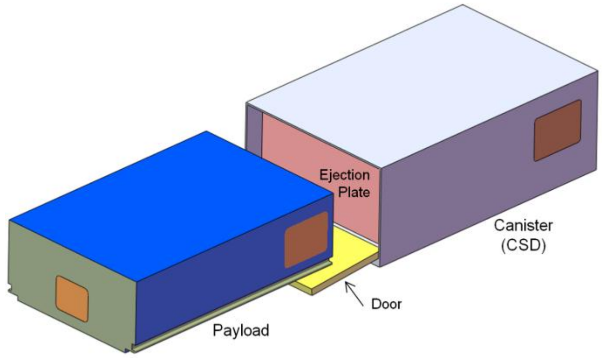


Figure 1: A 6U Payload and CSD

Figure 2: Need for 6U, 12U and 27U Payloads

ADVANCED FEATURES

The 6U, 12U and 27U payloads and canisters incorporate several features aimed at increasing performance, reducing complexity and minimizing integration costs.

1. Tabs: Two tabs run the length of the payload and are intended to be gripped by the canister, functioning similar to an automobile's brake caliper and rotor. This eliminates excessive payload chatter during launch. It also provides a predictable and thus model-able dynamic environment. This is significant for the launch vehicle, especially as payloads increase in mass. It is also reassuring for critical payloads with sensitive instruments. The tabs also serve the benefit of reducing manufacturing complexity as only the tab thickness is tightly controlled. Furthermore, eliminating the rails at the other two corners provides more room for body-mounted or deployable solar panels.
2. Mass: The density of the 6U-27U payloads has increased slightly allowing more mission enabling technologies. The considerable mass can reduce thermal extremes on-orbit and increase orbit life.
3. Non-Constrained Deployables: The payload has the option to use the canister as the means of constraining deployables. This reduces the complexity and volume of the restraint/release mechanism. It also eliminates a potential failure mode.
4. LV Electrical Interface: A DB-9 socket connector is the standardized canister interface to the LV. The pin-outs and electrical parameters are pre-defined, allowing the LV to plan ahead and eliminate variances that inevitability increase cost. The connector is located on a consistent face to enable the LV to size and locate their harness. This inexpensive and compact connector has significant flight heritage on several separation systems.
5. LV Mechanical Interface: The standard mounting pattern is a repeatable square grid pattern, independent of canister size. Additional patterns may be added to allow compatibility with existing deployers.
6. Placard: The payload and canisters may be integrated several months or years ahead of launch. A placard informs the LV of the contents, provides traceability, and reaffirms conformance to a specification giving the LV and primary payload assurance of mission success.

PAYLOAD AND CSD SPECIFICATIONS

Following are the 6U, 12U and 27U Payload and CSD specifications. The Payload, 2002206 Rev A, is a standalone specification intended for payload designers. They can build to this spec without need to reference the CSD. The CSD, 2002220 Rev -, is intimately linked to the Payload. It is intended to inform canister designers as well as launch service providers. The CSD designers must necessarily examine the payload spec to ensure compatibility. By examining both the payload and CSD specs the launch service provider has all information necessary for integration. The launch vehicle can allocate space for one or multiple CSDs without knowledge of the specific payload.

This is a standalone specification intended to inform payload designers. CSD manufacturers may also reference this specification to ensure compatibility.

FEATURES

These payloads are designed to be fully contained within Canisterized Satellite Dispensers (canister or CSD) during launch. A canister encapsulates the payload during launch and dispenses it on orbit. Canisters reduce risk to the primary payload and so maximize potential launch opportunity. Canisters also ease restrictions on payload materials and components. This specification currently encompasses three sizes of payloads. The 6U, 12U and 27U incorporate two tabs running the length of the ejection axis. The canister may grip these tabs, providing a secure, modelable, preloaded junction during launch. To maintain compatibility with existing standards the 6U can be made with typical rails as used in CubeSat. Note however with rails the payload is not preloaded in its canister and may chatter during launch.

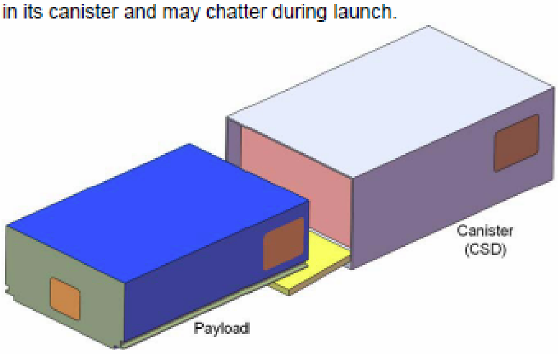


Figure 1: Payload deploying from Canister

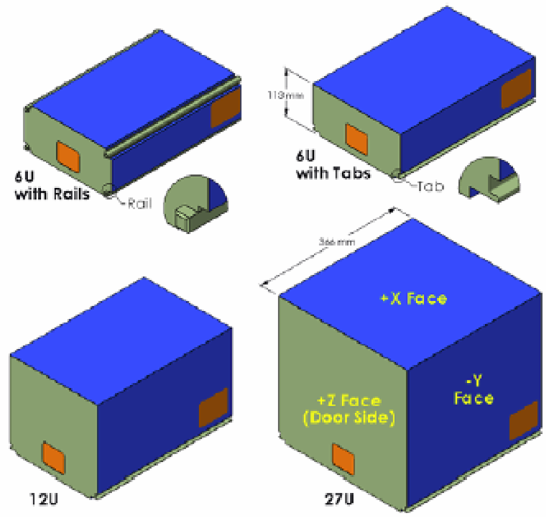


Figure 2: Payloads

CONTENTS

REVISION HISTORY

Revision	Date	Design	Review
-	18-Apr-2011	RH	WH
A	13-Jun-2011	RH	WH

Changes from previous revision:
Added Fig 1. Added Requirements. Added 12U and 27U to Fig. 2. Added Inhibit and Arm Circuit. Added Parameters. Added +/- Y face access zones. Added Benefits of Tabs. Allowed non-constrained deployables. Changed Environmental Testing. Changed Figs. 5-8. Added Test and Integration Flow. Added Additional Information. Added Authors.

INHIBIT AND ARM CIRCUIT

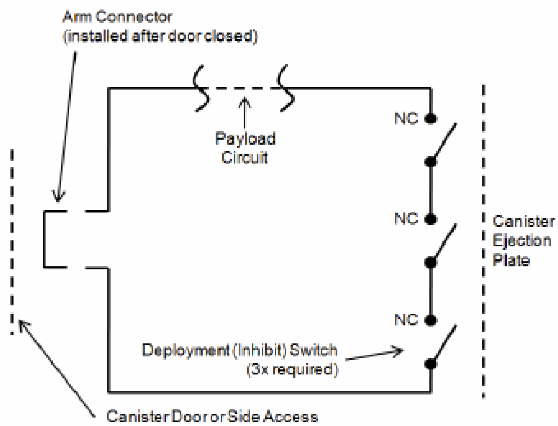


Figure 3: Payload inhibit and safe/arm circuit.

PARAMETERS

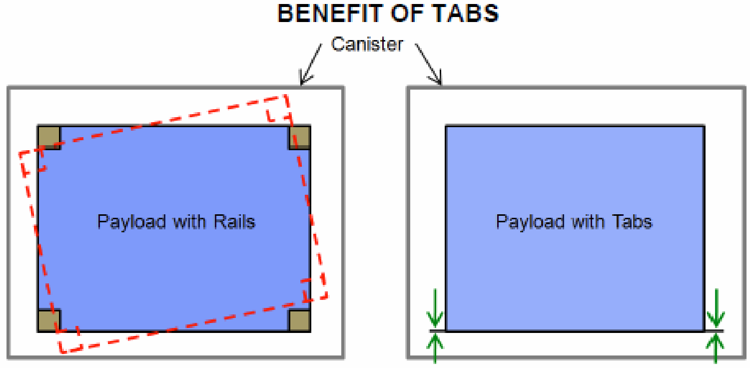
SYM	Parameter	Conditions	Unit	6U with Rails		6U with Tabs		12U with Tabs		27U with Tabs	
				Min	Max	Min	Max	Min	Max	Min	Max
M	Mass	At launch	kg	0	12	0	12	0	24	0	54
CMx	Center of mass, X	Stowed in canister	mm	30	70	10	70	55	125	100	180
CMY	Center of mass, Y	Stowed in canister	mm	-40	40	-40	40	-40	40	-60	60
CMz	Center of mass, Z	Stowed in canister	mm	133	233	133	233	133	233	133	233
Depth	Maximum payload depth, +X dimension		mm	-	-	0	106.4	0	219.1	0	331.8
Width	Maximum payload width from origin, ±Y dimension		mm	-	-	0	119.5	0	119.5	0	175.9
Tab Width	±Y dimension		mm	-	-	237.6	238.0	237.6	238.0	350.3	350.7
Tab Length	+Z dimension		mm	-	-	360.9	365.9	360.9	365.9	360.9	365.9
DSx	+X dimension defining allowable zone for deployment switches		mm	-	-	-	100	-	212	-	325
FDS	Force from deployment switches, summated, Z axis	When contacting CSD ejection plate	N	0	2.2	0	2.2	0	2.2	0	2.2
DDS	Payload separation from ejection plate necessary to change deployment switch state, Z axis		mm	1.3	12	1.3	12	1.3	12	1.3	12
FFD	Friction force imparted on deployables from canister walls during ejection, summated		N	0	2.0	0	2.0	0	2.0	0	2.0
FND	Normal force deployables impart on canister walls during ejection, per wall		N	0	4.0	0	4.0	0	4.0	0	4.0
EL	External load on payload, any direction	supported solely by tabs or rails	g	29	(1)	29	(1)	23	(1)	16	(1)
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	Canister de-pressurization rate	During launch	psi/sec	0	0.5	0	0.5	0	0.5	0	0.5

(1) Load increases with reduced payload mass. Load[g] = 51-8.75*ln(mass[kg]).

COMMON REQUIREMENTS

1. Tabs or rails shall be 100% continuous hard anodized aluminum per MIL-A-8625 or similar. Minimum 0.001 inch total thickness (0.0005 penetration + 0.0005 build-up). Teflon impregnation is acceptable. Maximum surface roughness of rails = 0.8 µm Ra.
2. No debris shall be generated that will inhibit separation.
3. Deployment (inhibit) switches shall reside in specified zone on -Z face. Will activate upon contact with canister ejection plate.
4. Safe/Arm plug, if necessary, shall reside in specified zone on +Z, +Y, or -Y face.
5. All non-constrained deployables shall be hinged near the +Z face to minimize snagging hazards during ejection.
6. -Z face of payload shall withstand a 200 N force imparted by canister ejection plate during launch or ejection.
7. Payload may be electrically grounded by contacting canister ejection plate within inhibit switch zone.
8. Perform fit-check of payload with canister at earliest possible time.

BENEFIT OF TABS



Payload may vibrate in canister because of small gap between rails and canister walls.

Tabs guarantee an invariant load path, allowing useful predictions of dynamic response.

6U, 12U & 27U PAYLOADS WITH TABS

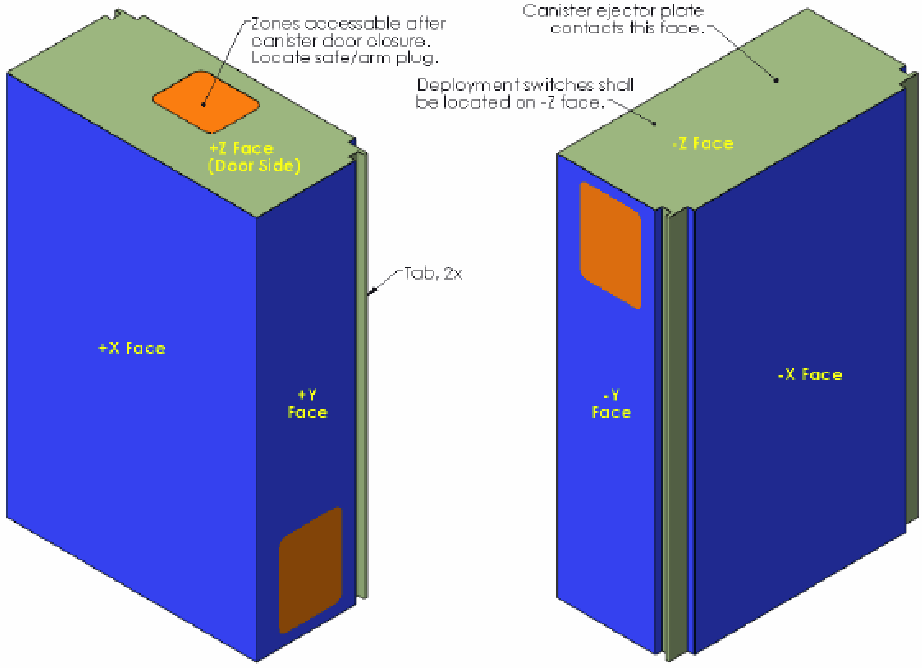


Figure 4: Tabbed payload (6U shown)

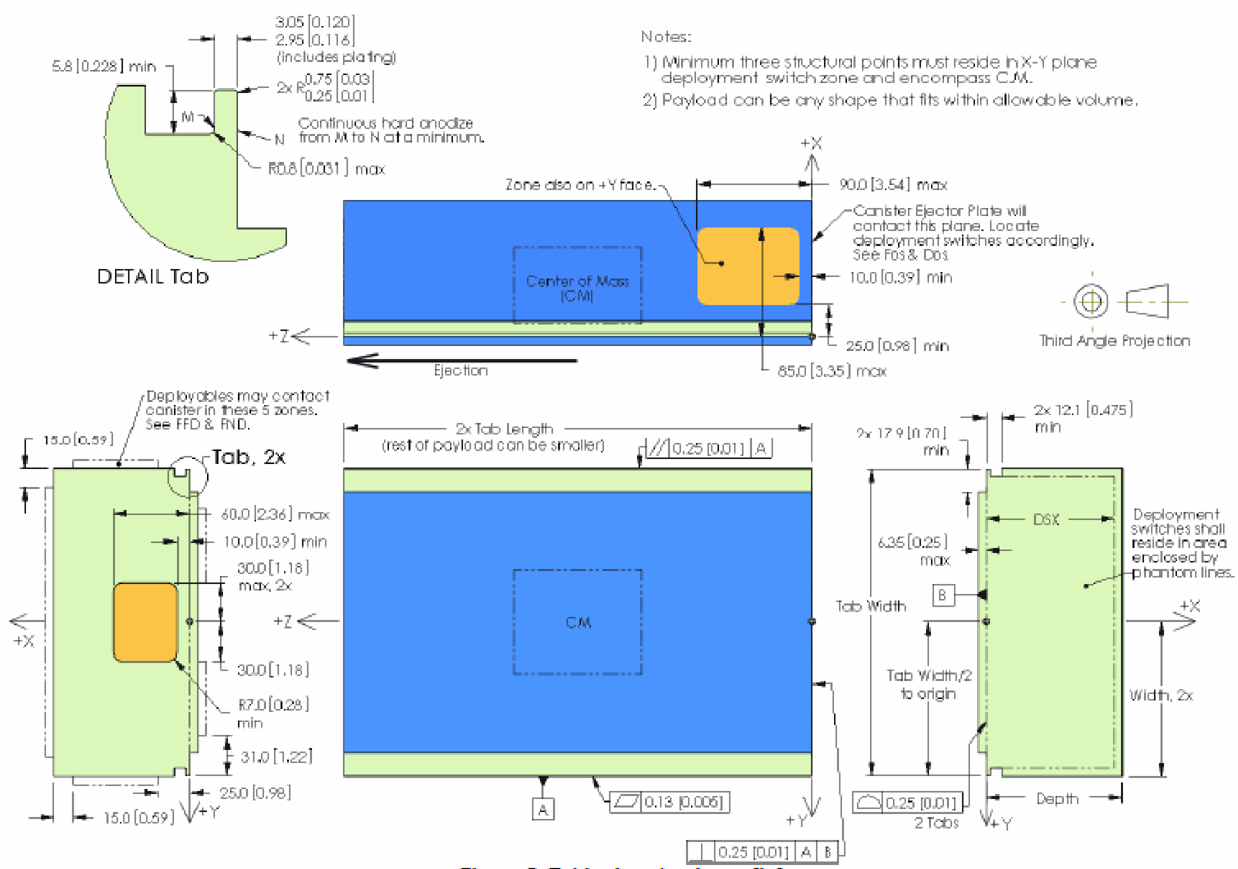


Figure 5: Tabbed payload, mm [in]

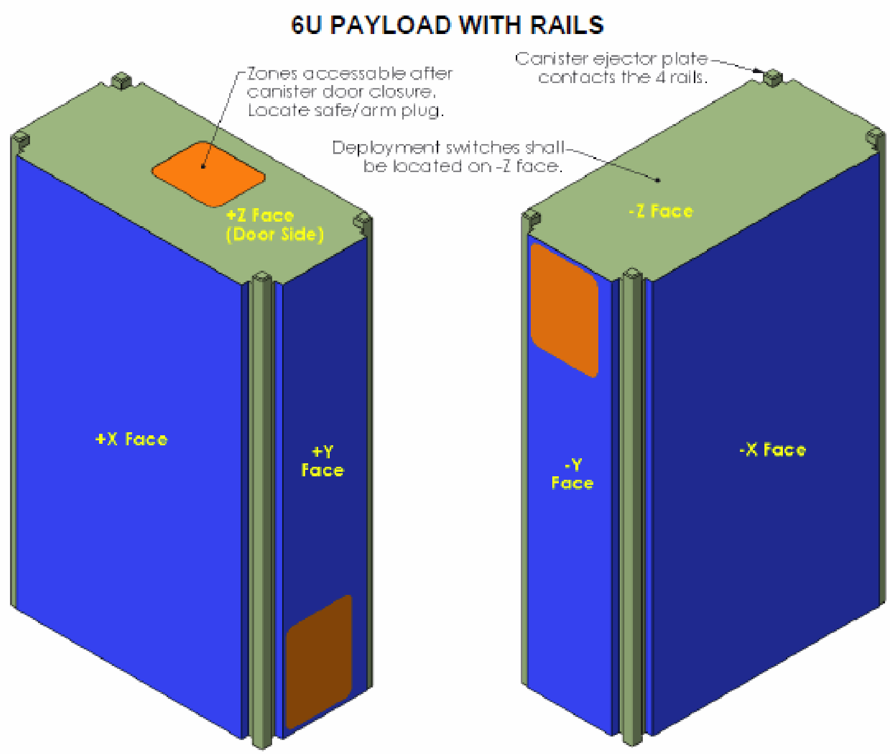


Figure 6: Payload with rails (6U only)

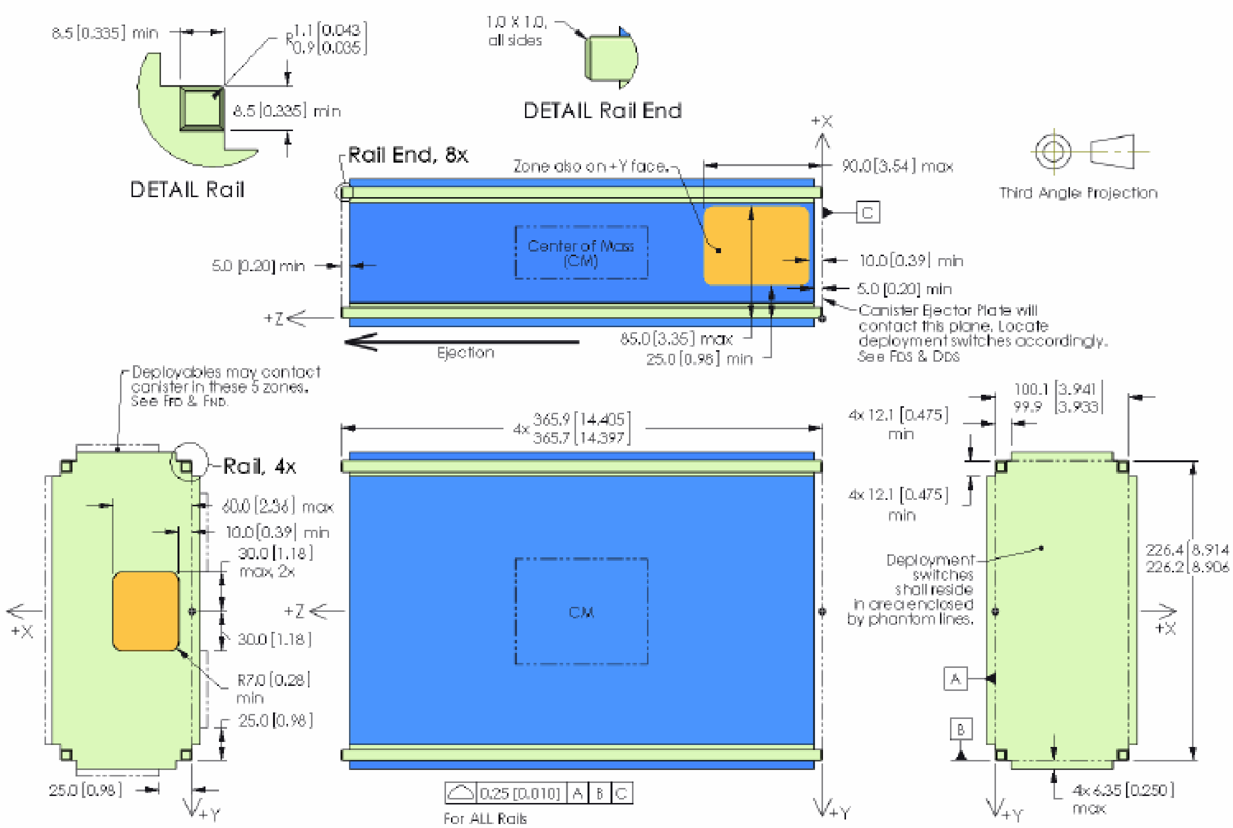
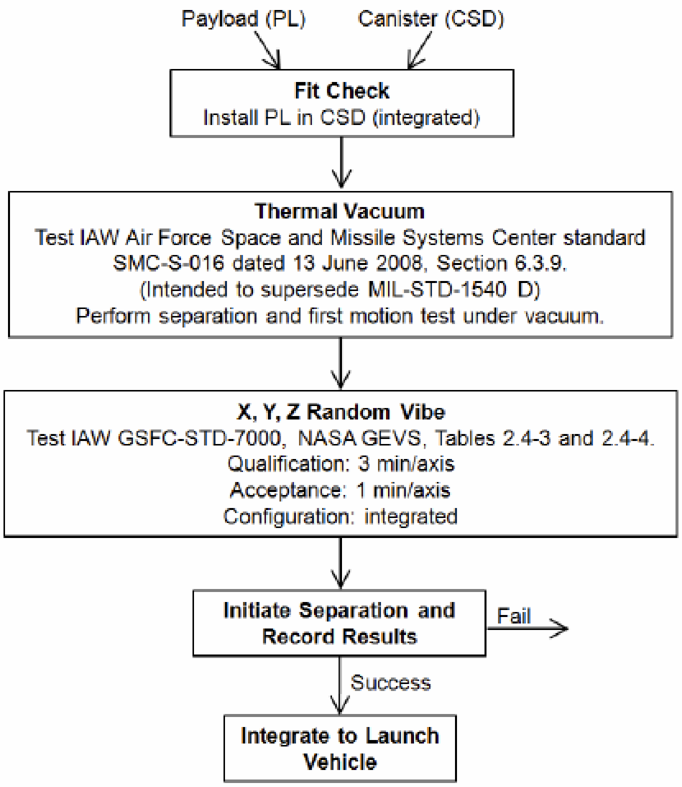


Figure 7: Payload with rails (6U only), mm [in]

TEST AND INTEGRATION FLOW

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



ADDITIONAL INFORMATION

Verify this is the latest revision of the specification by visiting www.planetarysystemscorp.com. Simple step models and 3D PDFs of the payloads and canisters are also available. Please contact Ryan Hevner, ryanh@planetarysystemscorp.com with questions or comments. Feedback is welcome in order to realize the full potential of this technology.

AUTHORS

Specification created by:
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Bruce Yost, NASA Ames
Jim White, Colorado Satellite Services
Andrew Kalman, Pumpkin Inc.
Adam Reif, Pumpkin Inc.

This specification is intended to inform CSD manufacturers and launch service providers. It is compatible with 2002206 Rev A "Payload Specification for 6U, 12U and 27U".

FEATURES

A Canisterized Satellite Dispenser (canister or CSD) is a box that encapsulates the payload (PL) during launch and dispenses it on orbit. Canisters reduce risk to the primary payload and so maximize potential launch opportunity. Their relatively small size enables placement on most launch vehicles (LV). Canisters also ease restrictions on payload materials and components. This specification currently encompasses canisters for three sizes of payloads. The 6U, 12U and 27U incorporate two tabs running the length of the ejection axis. The canister may grip these tabs, providing a secure, modelable, preloaded junction during launch. To maintain compatibility with existing standards the 6U can be made with typical rails as used in CubeSat. Note however with rails the payload is not preloaded in its canister and may chatter during launch.

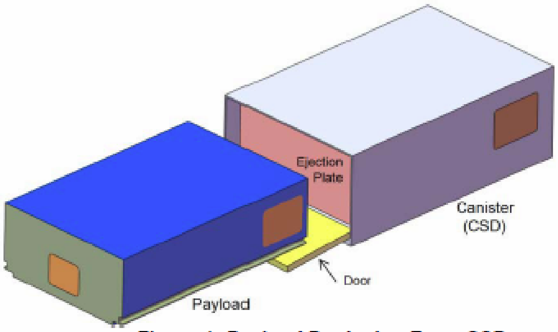


Figure 1: Payload Deploying From CSD

CONTENTS

REVISION HISTORY

Revision	Date	Design	Review
-	13-Jun-2011	RH	WH

Changes from previous revision:
This is the initial release.

COMMON REQUIREMENTS

1. Mounting surface to LV shall be electrically conductive.
2. Access panels to payload shall be removable with small flat or Phillips screwdriver or 3/32 in hex key. Torque spec, if applicable, shall be imprinted on CSD.
3. An ejection plate shall push on -Z face of payload to deploy. Plate shall fully encompass payload deployment switch zone and be flat to 0.5mm. See payload specification for deployment switch zone dimensions.
4. Payload shall be oriented in CSD per Figure 6.
5. Ejection Plate shall be electrically grounded to CSD walls. Payload side of ejection plate shall be conductive.

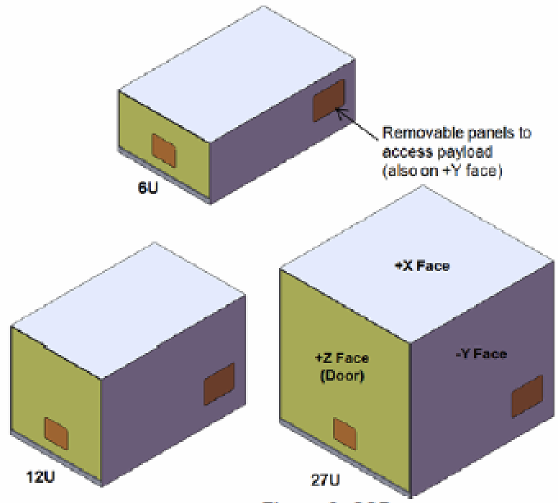


Figure 2: CSD

ELECTRICAL INTERFACE TO LV

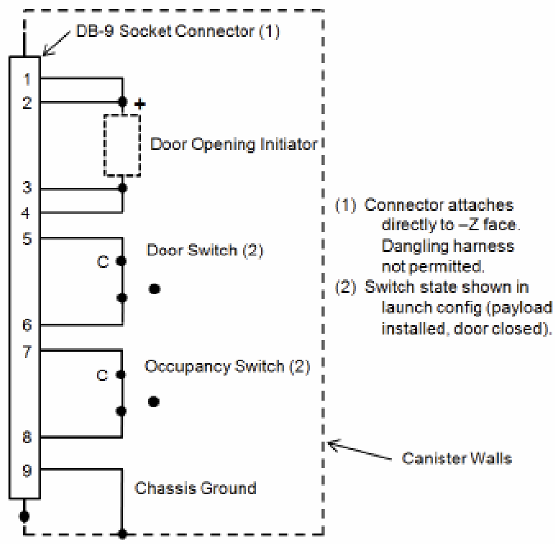


Figure 3: Electrical Interface to LV

PARAMETERS

SYM	Parameter	Conditions	Units	6U		12U		27U	
				Min	Max	Min	Max	Min	Max
M	Mass	Empty	kg	-	7.2	-	10.8	-	15.1
Depth	CSD depth, from origin, +X		mm	-	163	-	276	-	389
Width	CSD width, from origin, +/- Y		mm	-	140	-	140	-	195
Length	CSD length, from origin, +Z	Door closed	mm	-	470	-	470	-	470
ΔV	Payload ejection velocity	Max payload mass, infinite CSD mass	m/sec	0.5	5.0	0.5	5.0	0.5	5.0
V	Voltage provided from LV to open door	-34 to +71 °C, power to pins 1&2, return from pins 3&4	Vdc	22	36	22	36	22	36
I	Current available from LV to open door	-34 to +71 °C, power to pins 1&2, return from pins 3&4	A	5.0	-	5.0	-	5.0	-
T	Electrical pulse width provided from LV to open door	-34 to +71 °C, power to pins 1&2, return from pins 3&4	sec	4.0	10.0	4.0	10.0	4.0	10.0
Wire	Electrical wiring	Wiring shown in Figure 3.	AWG	20	26	20	26	20	26
RS	Switch terminal resistance	Closed circuit, door and occupancy switches	ohm	0.0	0.2	0.0	0.2	0.0	0.2
IIR	Inrush current capacity of switch	<0.5 sec, 30 Vdc, <10e-5 torr, Door and occupancy switches	A	-	4.0	-	4.0	-	4.0
ISS	Steady state current capacity of switch	30 Vdc, <10e-5 torr, door and occupancy switches	A	-	2.0	-	2.0	-	2.0
PT	Payload travel required for occupancy switch change state	+Z travel from launch position	mm	300	440	300	440	300	440
DP	Door position for door switch change of state	Angle (0 deg is closed)	deg	0.4	5.0	0.2	5.0	0.15	5.0
FEP	Ejection plate force on payload	During launch and deployment	N	0	200	0	200	0	200
LVF	LV flatness	Interface to CSD -X face	mm	0.0	0.3	0.0	0.3	0.0	0.5
TML	Total Mass Loss	Per ASTM E 595-77/84/90	%	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
DP	LV de-pressurization rate	During launch	psi/sec	0	0.5	0	0.5	0	0.5

PLACARD

Canister Complies with Specification 2002220 Rev ___
Payload Complies with Specification 2002206 Rev ___

Canister
Responsible Organization:
Contact Name, Email and Phone Number:

PN and SN:
Empty Mass [kg]:

Payload
Responsible Organization:
Contact Name, Email and Phone Number:

PN and SN:
Installed Mass [kg]:
Installation Date:

Assembly
Total Launch Mass [kg]:
Ready for Launch (Date and Name):

Requirements
1. Locate on +Z face (door).
2. Minimum text height 0.12 in.
3. Engrave, etch or stamp.
4. Tag shall be replaceable.
5. Text shall be legible in poorly lit room and under direct sunshine.
6. May add additional information as desired.

6U, 12U & 27U CSD

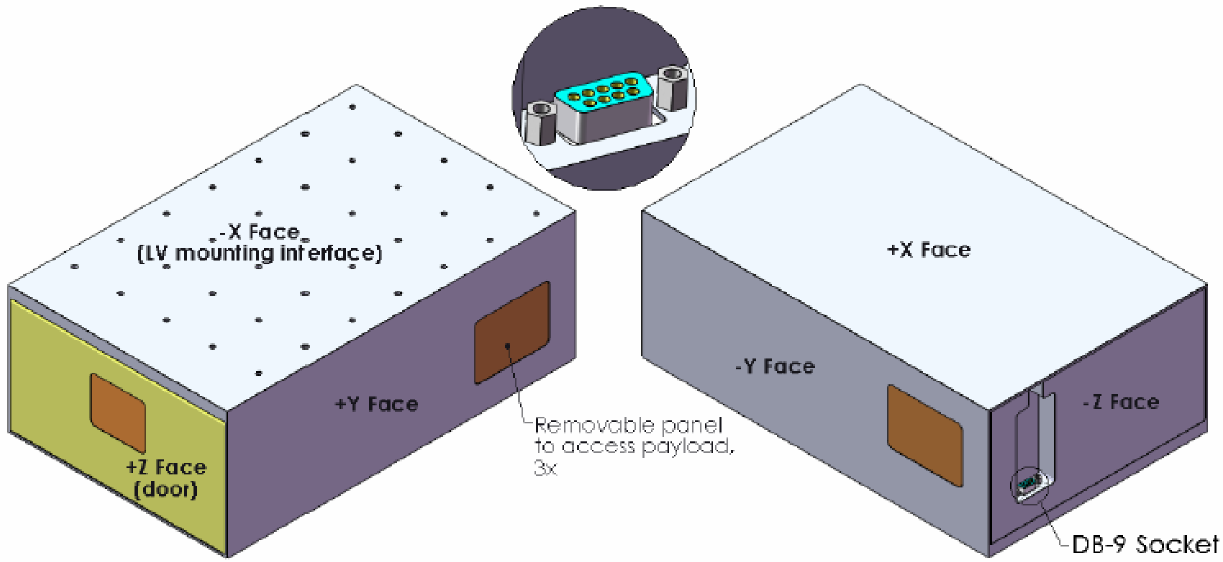


Figure 4: CSD, 6U shown

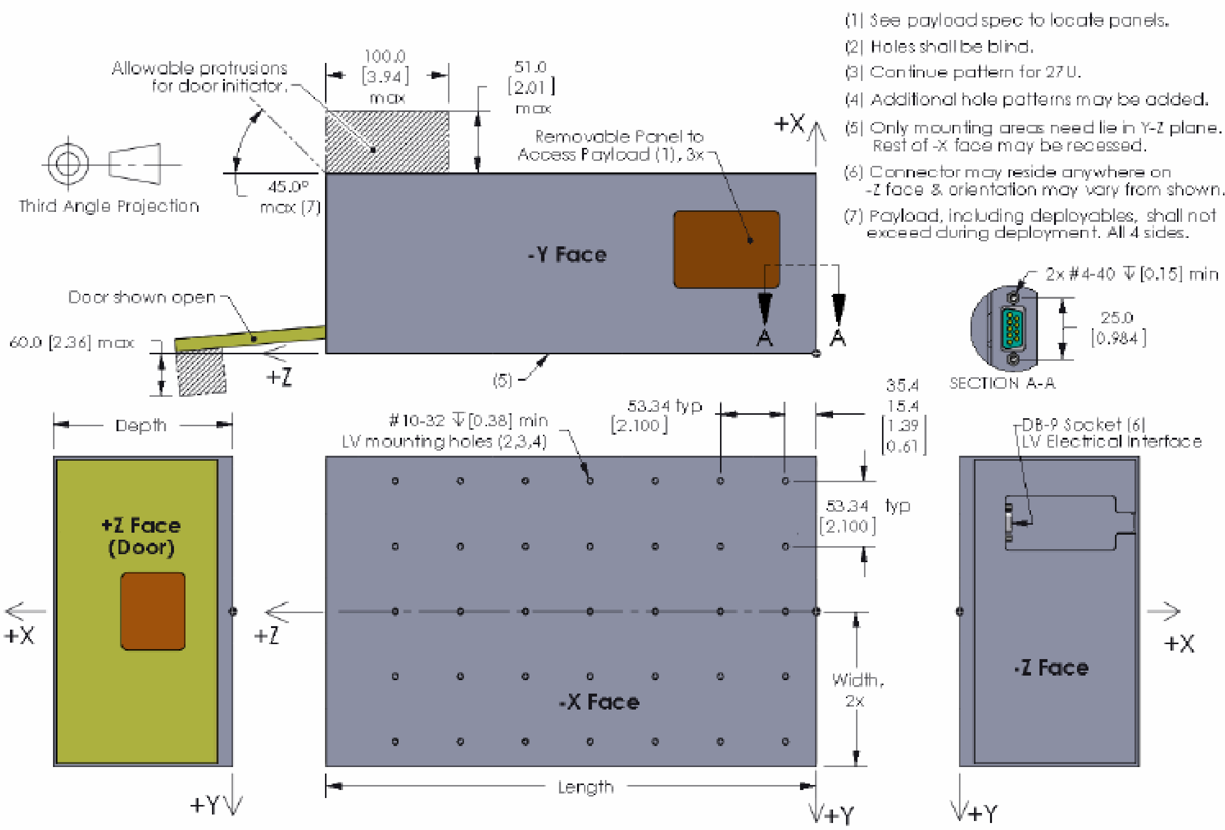


Figure 5: CSD, mm [in]

2002220 Rev - CSD Specification for 6U, 12U and 27U 13-June-2011 3 / 4

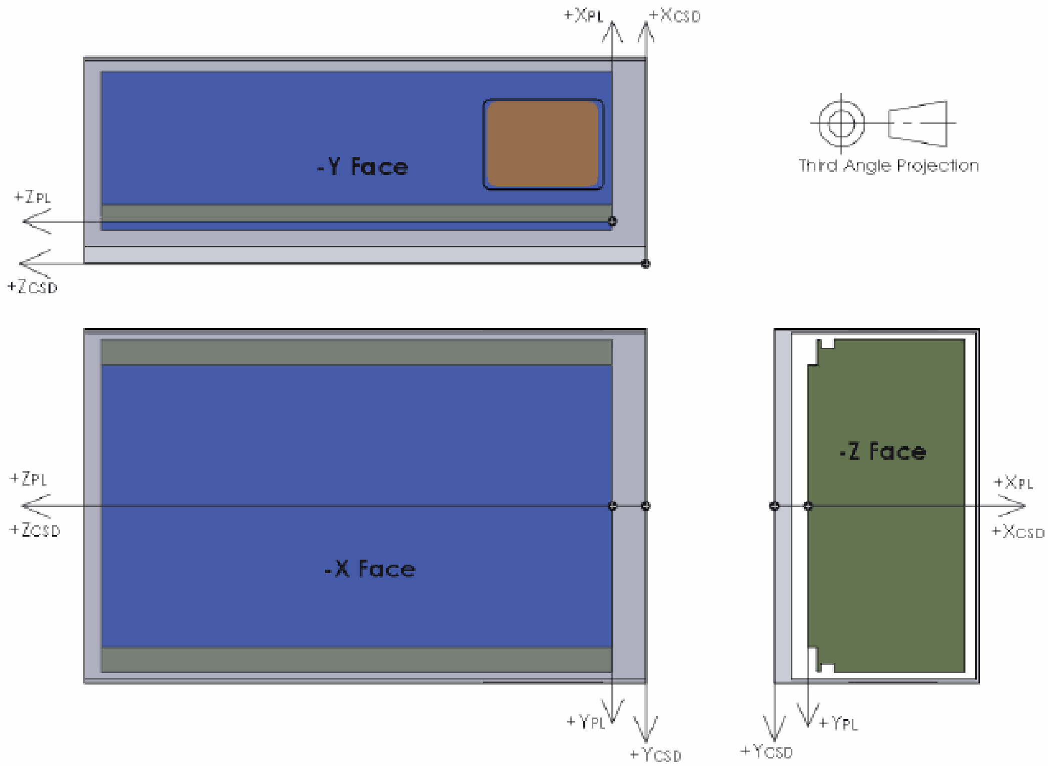
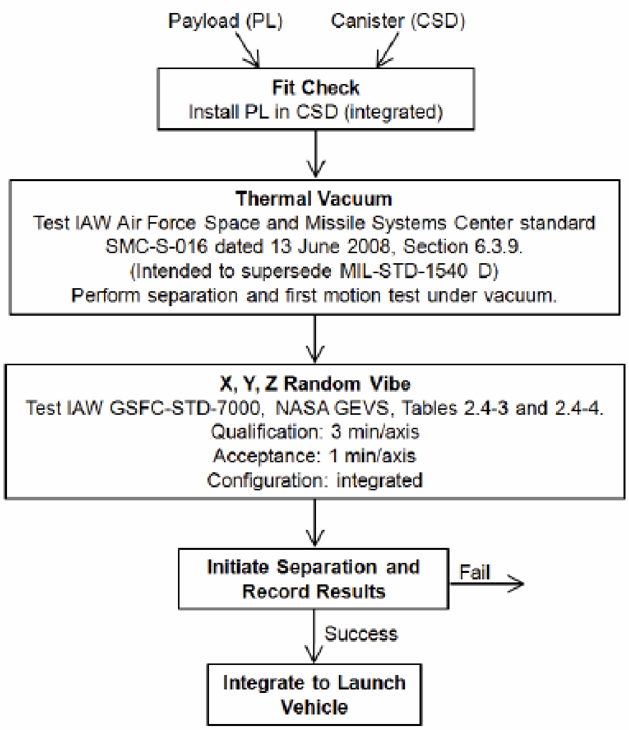


Figure 6: Payload in CSD

TEST AND INTEGRATION FLOW

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



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