

Document Classification	
X	Public Domain

6U CubeSat Design Specification
Rev. PROVISIONAL

(CP-CDS-PROVISIONAL)

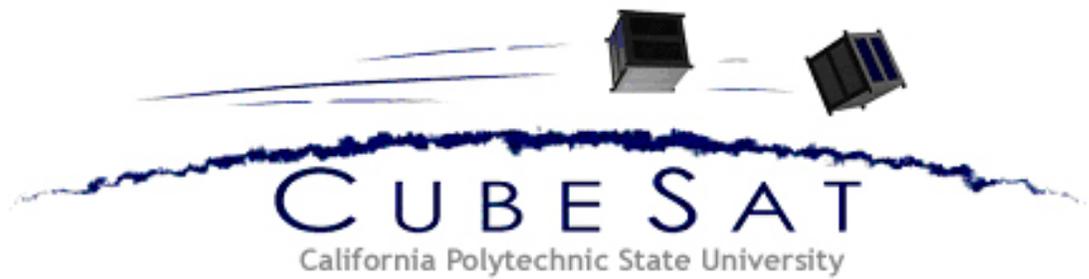


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List of Acronyms

ADC	Attitude Determination and Control
AFSPCMAN	Air Force Space command Manual
CAC	CubeSat Acceptance Checklist
Cal Poly	California Polytechnic State University, San Luis Obispo
CDS	CubeSat Design Specification
cm	Centimeters
CSD	Canisterized Satellite Dispenser
CVCM	Collected Volatile Condensable Mass
C&DH	Command and Data Handling
DAS	Debris Assessment Software
FAA	Federal Aviation Administration
FCC	Federal Communication Commission
GEVS	General Environmental Verification Standard
GSFC	Goddard Space Flight Center
IARU	International Amateur Radio Union
IDD	Interface Design Document
ISIS	Innovative Solutions In Space
kg	Kilogram
LSP	Launch Services Program
LV	Launch Vehicle
LVC	Launch Vehicle Contractor
mA	milli-Amps
MIL-STD	Military Standard
MIN	Minimum
mm	Millimeters
NASA	National Aeronautics and Space Administration
NLAS	Nanosatellite Launch Adapter System
NOAA	National Oceanic and Atmospheric Administration
NPR	NASA Procedural Requirements
P-POD	Poly Picosatellite Orbital Deployer
PSC	Planetary Systems Corporation
RBF	Remove Before Flight

REQ	Requirement
Rev.	Revision
RF	Radio Frequency
RTC	Real Time Clock
SLO	San Luis Obispo
SMC-S	Space and Missile Systems Center Standard
SSDL	Space Systems Development Lab
STD	Standard
TML	Total Mass Loss
UL	Underwriters Laboratories
µm	Micrometer
U.S.	United States

Applicable Documents

The following documents were used to guide the creation of this document.

General Documentation:

Air Force Space Command Manual 91-710, Range Safety User Requirements Manual (AFSPCMAN 91-710)

General Environmental Verification Standard for GSFC Flight Programs and Projects (GSFC-STD-7000 A)

Launch Services Program Program Level P-POD and CubeSat Requirements Document (LSP-REQ-317.01 B)

NASA Procedural Requirements for Limiting Orbital Debris (NPR 8715.6A)

Space and Missile Systems Center Standard Test Requirements for Launch, Upper-Stage and Space Vehicles (SMC-S-016)

Standard Materials and Processes Requirements for Spacecraft (NASA-STD-6016)

Dispenser Specific Documentation:

Please be advised that the documents listed here may not be the most up to date versions available. Please use the link provided for each dispenser to find the most recent revision.

Innovative Solutions In Space (ISIS) CubeSat drawings
<http://www.isispace.nl>

Planetary Systems Corporation Canisterized Satellite Dispenser (CSD) Data Sheet (2002337) and Payload Spec (2002367)
<http://www.planetarysystemscorp.com>

Tyvak Nanosatellite Launch Adapter System (NLAS) Mk. II User Guide (TK-NLASUG-Rev1)
<http://tyvak.com>

1. Introduction

1.1 Overview

Started in 1999, the CubeSat Project began as a collaborative effort between Prof. Jordi Puig-Suari at California Polytechnic State University (Cal Poly), San Luis Obispo, and Prof. Bob Twiggs at Stanford University's Space Systems Development Laboratory (SSDL). The purpose of the project is to provide a standard for design of picosatellites to reduce cost and development time, increase accessibility to space, and sustain frequent launches. Presently, the CubeSat Standard is being used to develop picosatellites by high schools, universities, Government agencies and private companies all over the world. A 1U CubeSat is a 10 cm cube with a mass of up to approximately 1.5 kg. To view the most updated versions of all CubeSat Design Specifications, please visit: <http://cubesat.org> and click on: "CubeSat Design Specification".

As Developers have continued to push the limits of CubeSats, there has been an increasing demand for a larger satellite standard within the community. The 6U CDS provides a means to provide standardized development for larger picosatellites. If you have any questions about this document, please contact Cal Poly. You may visit the CubeSat website at <http://cubesat.org> for more information.

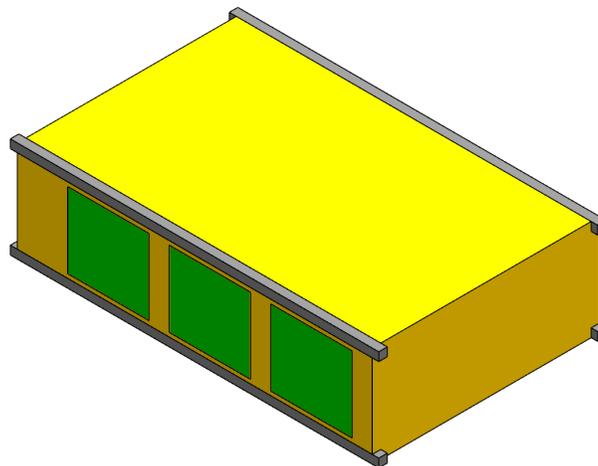


Figure 1: 6U CubeSat Isometric view with highlighted optional Access Port locations

1.2 Purpose

The primary mission of the CubeSat Program is to provide access to space for small payloads. The primary responsibility of companies developing 6U Dispensers is to ensure the safety of the CubeSat and protect the launch vehicle (LV), primary payload, and other CubeSats during launch. CubeSat Developers should play an active role in ensuring the safety and success of CubeSat missions by implementing good engineering practice, testing, and verification of their systems. Failures of CubeSats, 6U Dispensers, or interface hardware can damage the LV or a primary payload and put the entire CubeSat Program in jeopardy. As part of the CubeSat Community, all participants have an obligation to ensure safe operation of their systems and to meet the design and minimum testing requirements outlined in this document.

Requirements in this document will typically be superseded by the requirements of the launch provider.

1.3 Mission Requirements

Most CubeSat missions employ an organization to be responsible for all mission coordination duties. That roll is usually referred to as the Mission Integrator, whose responsibilities can include coordinating safety documentation with Range Safety, interfacing with the CubeSat Developers, ICD requirement verifications with CubeSat Developers and the Launch Vehicle Contractor (LVC), acting as the point of contact for licensing agencies, CubeSat to dispenser integration and testing, and coordinating with the JSpOC for pre- and post-launch identification of each CubeSat in orbit. In essence, the Mission Integrator acts as the interface between the CubeSat Developer and the LVC, and will provide the official mission requirements to the CubeSat Developer.

Although mission requirements are oftentimes similar to the requirements in the CDS, the CubeSat Developer will only be responsible for meeting the requirements provided by the Mission Integrator. The requirements in this document are meant for preliminary design purposes, and are written conservatively to allow for the best chances of compatibility with any launch vehicle.

1.4 Waiver Process

Waivers are required by any spacecraft deviating from the specifications defined in the mission requirements. Typically, the Mission Integrator will review the request with guidance from the LVC, resolve any questions, and determine if there are any additional tests, analyses or costs to support the waiver. This process is only valid after the CubeSat has been manifested on a mission, and the Mission Integrator is known.

If the CubeSat has not been manifested yet and deviates from a requirement in the CDS, the Developer can complete the waiver inquiry request form (see appendix A) and submit it to Cal Poly (cubesat@gmail.com) for an informal review. Cal Poly cannot make a determination as to whether the deviation will be acceptable to a future launch vehicle provider, but can provide guidance.

Developers should realize that each requirement deviation potentially reduces the chances of finding a suitable launch opportunity.

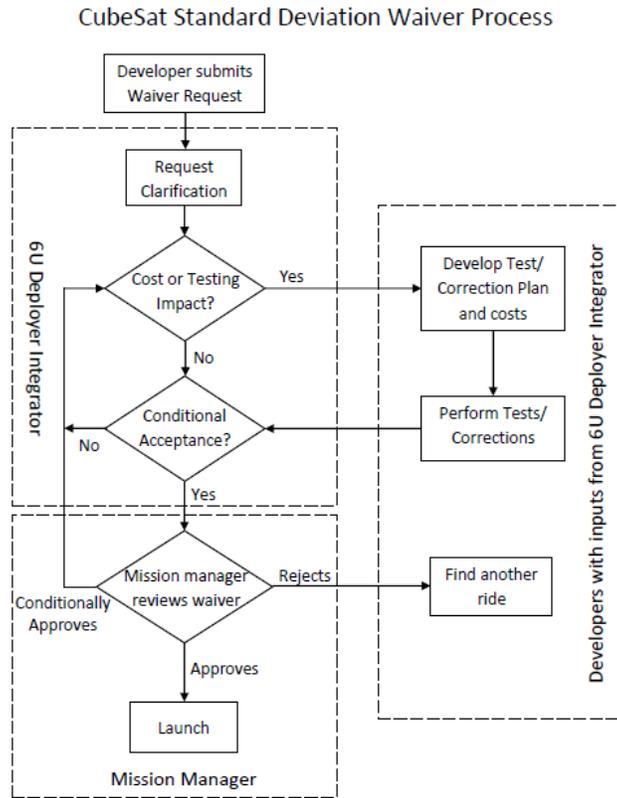


Figure 2: CubeSat Standard Deviation Waiver Process Flow Diagram

2. 6U Dispenser

2.1 Interface

The 6U Dispenser is designed to carry a standard 6U CubeSat and serve as the interface between the CubeSat and LV. Essentially, it's a rectangular box that utilizes a hinged door and spring mechanism to deploy its payload. A deployment signal sent from the LV actuates the release mechanism to open the door, and the CubeSat is ejected from the dispenser.

Multiple companies are developing 6U Dispensers which all adhere to one of two standardized constraint systems. The first is very similar to the rail system utilized by the Poly Picosatellite Orbital Deployer (P-POD), and is used on the Tyvak and Innovative Solutions In Space (ISIS) dispensers. The second system, developed by Planetary Systems Corporation (PSC), utilizes two thinner rails henceforth referred to as 'tabs' that run along the length of the CubeSat. The PSC 6U Dispenser employs a constraint mechanism that clamps onto these tabs and, when integrated, creates a stiff invariant load path.

In both cases, the deployment force is provided by a main spring driving the internal pusher plate. The pusher plate, in turn, interfaces with the CubeSat, which glides along the 6U Dispenser rails as it's ejected into orbit. Mechanical requirements for the rail system CubeSat are outlined in Section 3.2, and the mechanical requirements for tabbed CubeSats can be found at planetarysystemcorp.com. Developers are encouraged to explore both options to determine which is optimal for their needs. Due to the mechanical differences in dispenser designs, CubeSats might not be compatible with both types of dispensers.

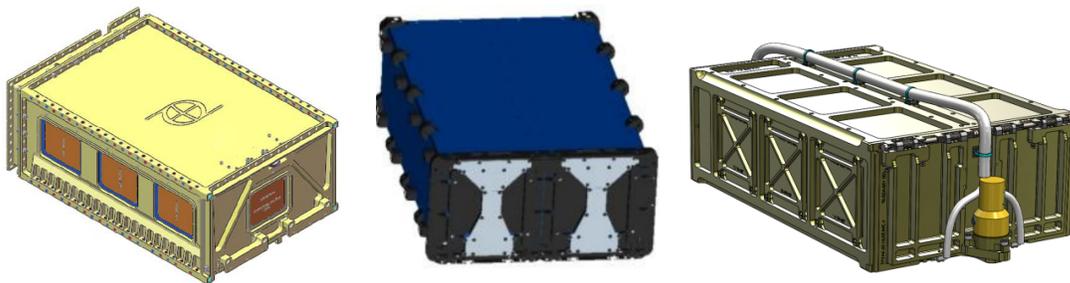


Figure 3a, 3b and 3c: Three Dispensers for 6U CubeSats designed by Planetary Systems Corporation (left) ISIS (center) and Tyvak (right)

3. CubeSat Specification

3.1 General Requirements

- 3.1.1 All parts shall remain attached to the CubeSats during launch, ejection and operation. No additional space debris will be created.
- 3.1.2 No pyrotechnics shall be permitted.
- 3.1.3 Any propulsion systems shall be designed, integrated, and tested in accordance with AFSPCMAN 91-710 Volume 3.
- 3.1.4 Propulsion systems shall have at least 3 independent inhibits to activation.
- 3.1.5 Total stored chemical energy will not exceed 100 Watt-Hours.
 - 3.1.5.1 **Note:** This requirement is derived from the Federal Aviation Administration (FAA) requirement for lithium battery capacities that are allowed to be hand carried on to commercial aircraft.
- 3.1.6 CubeSat hazardous materials shall conform to AFSPCMAN 91-710, Volume 3.
- 3.1.7 CubeSat materials shall satisfy the following low out-gassing criterion to prevent contamination of other spacecraft during integration, testing, and launch. A list of NASA approved low out-gassing materials can be found at: <http://outgassing.nasa.gov>
 - 3.1.7.1 CubeSat materials shall have a Total Mass Loss (TML) $\leq 1.0\%$
 - 3.1.7.2 CubeSat materials shall have a Collected Volatile Condensable Material (CVCM) $\leq 0.1\%$
- 3.1.8 **Note:** Some launch vehicles hold requirements on magnetic field strength. As a general guideline, it is advised to limit the magnetic field outside the CubeSat static envelope to 0.5 Gauss above Earth's magnetic field, while the CubeSat is integrated in the dispenser.
- 3.1.9 The CubeSat shall be designed to accommodate ascent venting per ventable volume/area < 2000 inches.

3.2 *CubeSat Mechanical Requirements*

6U CubeSats are picosatellites with dimensions and features outlined in the 6U CubeSat Specification Drawing (Appendix B). These requirements are applicable for all dispensers not utilizing the tab constraint method. CubeSats designed with tabs can find those specific requirements at the PSC website (planetarysystemscorp.com). General features of all CubeSats without tabs include:

- 3.2.1 The CubeSat shall use the coordinate system as defined in Appendix B. The origin of the CubeSat coordinate system is located at the geometric center of the CubeSat.
 - 3.2.1.1 The 6U CubeSat configuration and physical dimensions shall be per the appropriate section of Appendix B.
- 3.2.2 The $-Z$ face of the CubeSat will be inserted first into the 6U Dispenser.
- 3.2.3 No components on the yellow shaded faces shall exceed 10 mm normal to the surface.
 - 3.2.3.1 When completing a CubeSat Acceptance Checklist (CAC), protrusions will be measured from the plane of the rails.
- 3.2.4 Deployables shall be constrained by the CubeSat, not the 6U Dispenser.
 - 3.2.4.1 **Note:** This requirement is derived from launch vehicle requirements.
- 3.2.5 Rails shall have a minimum width of 8.5mm.
- 3.2.6 Rails will have a surface roughness less than 1.6 μm .
- 3.2.7 The edges of the rails will be rounded to a radius of at least 1 mm.
- 3.2.8 At least 75% of the rail will be in contact with the 6U Dispenser rails. 25% of the rails may be recessed, and no part of the rails will exceed the specification.
- 3.2.9 The maximum mass of a 6U CubeSat shall be 12.00 kg.
 - 3.2.9.1 **Note:** Larger masses may be evaluated by the Mission Integrator on a mission specific basis.
- 3.2.10 The CubeSat center of gravity shall be located within 4.5 cm from its geometric center in the X direction, within 2 cm from its geometric center in the Y direction, and within 7 cm from its geometric center in the Z direction
- 3.2.11 Typically, Aluminum 7075, 6061, 6082, 5005, and/or 5052 are used for both the main CubeSat structure and the rails. If materials other than aluminum are used, the CubeSat Developer should contact the Mission Integrator or dispenser manufacturer.
- 3.2.12 The CubeSat rails and standoff, which contact the 6U Dispenser rails and ejector plate, shall be hard anodized aluminum to prevent any cold welding within the 6U Dispenser.

3.3 *Electrical Requirements*

Electronic systems will be designed with the following safety features. These requirements are applicable for all dispensers.

- 3.3.1 The CubeSat power system shall be at a power off state to prevent the CubeSat from activating any powered functions while integrated in the 6U Dispenser from the time of delivery to the LV through on-orbit deployment. CubeSat powered functionality includes a variety of subsystems such as Command and Data Handling (C&DH), RF Communication, Attitude Determination and Control (ADC), and deployable mechanism actuation. CubeSat power systems include all battery assemblies, solar cells, and coin cell batteries.
 - 3.3.1.1 Powered-On Real Time Clocks (RTC) may be permitted, if they satisfy the following requirements.
 - 3.3.3.1.1 Real time clock circuits shall be isolated from the CubeSat's main power system.
 - 3.3.3.1.2 Real time clock frequencies shall be less than 320 kHz.
 - 3.3.3.1.3 Real time clock circuit(s) shall be current limited to less than 10 mA.
- 3.3.2 The CubeSat shall have, at a minimum, one deployment switch, which is actuated while integrated in the 6U Dispenser.
 - 3.3.2.1 In the actuated state, the CubeSat deployment switch shall electrically disconnect the power system from powered functions.
 - 3.3.2.2 The deployment switch shall be in the actuated state at all times while integrated in the 6U Dispenser.
 - 3.3.2.3 If the CubeSat deployment switch toggles from the actuated state and back, the satellite shall reset to a pre-launch state, including reset of transmission and deployable timers.
- 3.3.3 The CubeSat shall include a RBF pin. The RBF pin shall cut all power to the satellite once it is inserted into the satellite.
 - 3.3.3.1 The RBF pin shall protrude no more than 10 mm from the rails (or within the allowable CubeSat volume on tabbed dispensers, see planetarysystemscorp.com for details) when fully inserted into the satellite.
 - 3.3.3.2 Access to the CubeSat is not guaranteed during or after integration. The RBF pin shall be removed from the CubeSat before integration into the 6U Dispenser, if the dispenser does not have access ports.
- 3.3.4 CubeSats shall incorporate battery circuit protection for charging/discharging to avoid unbalanced cell conditions. Additional manufacturer documentation and/or testing will be required for modified, customized, or non-UL-listed cells.
- 3.3.5 The CubeSat shall have at least three independent RF inhibits to prohibit inadvertent radio frequency (RF) transmission. An inhibit is a physical device between a power source and a hazard. A timer is not considered an independent inhibit.
 - 3.3.5.1 **Note:** Some launch vehicle providers will only require one or two independent inhibits depending on the CubeSat's RF power output. However, the use of three independent inhibits is highly recommended and can reduce required documentation and analyses.

3.4 *Operational Requirements*

CubeSats will meet certain requirements pertaining to integration and operation to meet legal obligations and ensure the safety of other CubeSats. These requirements are applicable for all dispensers. Dispenser specific options are available, however additional options may limit launch opportunities.

- 3.4.1 Operators will obtain and provide documentation of proper licenses for use of radio frequencies per their country's requirements.
 - 3.4.1.1 For amateur frequency use, this requires proof of frequency coordination by the International Amateur Radio Union (IARU). Applications can be found at www.iaru.org.
 - 3.4.1.2 **Note:** For CubeSats being operated in the U.S., amateur radio regulations can be found here: <http://www.arrl.org/part-97-amateur-radio>
- 3.4.2 The CubeSat will comply with its country's radio license agreements and restrictions.
- 3.4.3 CubeSat mission design and hardware shall be in accordance with NPR 8715.6 to limit orbital debris.
 - 3.4.3.1 Any CubeSat component shall re-enter with energy less than 15 Joules.
 - 3.4.3.2 Developers will be ready to provide orbital debris mitigation data if requested by the licensing agency or Mission Integrator.
 - 3.4.3.3 **Note:** Analysis can be conducted to satisfy the above requirements with NASA DAS software, available at <http://orbitaldebris.jsc.nasa.gov/mitigate/das.html>
- 3.4.4 All deployables such as booms, antennas, and solar panels shall wait to deploy a minimum of 30 minutes after the CubeSat's deployment switch(es) are activated during 6U Dispenser ejection.
- 3.4.5 No CubeSats shall generate or transmit any RF signal from the time of integration into the 6U Dispenser through 45 minutes after on-orbit deployment from the 6U Dispenser. However, the CubeSat can be powered on following deployment from the 6U Dispenser.
- 3.4.6 Private entities (non-U.S. Government) under the jurisdiction or control of the United States who propose to operate a remote sensing space system (satellite) may need to have a license as required by U.S. law. For more information visit <http://www.nesdis.noaa.gov/CRSRA/licenseHome.html>. Click on the Application Process link under the Applying for a License drop down section to begin the process.
- 3.4.7 The Mission Integrator may conduct a fit check in which the CubeSat Developer hardware will be inspected and integrated into the 6U Dispenser or Test 6U Dispenser. A final fit check will be conducted prior to launch. The CubeSat Acceptance Checklist (CAC) can be used to verify compliance of the specification (CAC can be found in the appendix of this document or online at <http://cubesat.org>).

4. Testing Requirements

Before detailing the typical CubeSat testing requirements, it is important to point out that all testing levels and requirements are mission specific and vary with every launch. The examples provided in this document, are typically, the most stringent to encompass requirements from most of the possible launch opportunities to date.

Testing will be performed to meet the launch provider requirements as well as any additional testing requirements deemed necessary to ensure the safety of the CubeSats, 6U Dispenser, and the primary mission. If the launch vehicle environment is unknown, The General Environmental Verification Standard (GEVS, GSFC-STD-7000A) and SMC-S-016 can be used to derive testing requirements. GSFC-STD-7000A and SMC-S-016 are useful references when defining testing environments and requirements. However, the test levels defined in GSFC-STD-7000A and SMC-S-016 are not guaranteed to encompass or satisfy all LV testing environments. Test requirements and levels that are not generated by the launch provider or the Mission Integrator are considered unofficial. The launch provider testing requirements will supersede testing environments from any other source. Typically, all CubeSats will undergo the following tests.

4.1 Random Vibration

Random vibration testing shall be performed to the levels and duration as defined by the Mission Integrator.

4.2 Thermal Vacuum Bakeout

Thermal vacuum bakeout shall be performed to ensure proper outgassing of components. The test specification will be defined by the Mission Integrator.

4.3 Shock Testing

Shock testing is typically not required for CubeSats. However, if necessary, shock testing shall be performed as defined by the Mission Integrator.

4.4 Visual Inspection

Visual inspection of the CubeSat and measurement of critical areas will be performed per the appropriate 6U CAC (Appendix C) or as defined by the Mission Integrator.

4.5 CubeSat Testing Philosophy

This section outlines a conservative test flow approach for CubeSats to meet environmental test requirements for launch. The CubeSat shall be subjected to either qualification or protoflight testing as defined in the CubeSat Testing Flow Diagram, shown in Figure 4. The test levels and durations will be supplied by the Mission Integrator.

4.5.1 Qualification

Qualification testing is performed on an engineering unit that is identical to the flight model CubeSat. Qualification levels will be determined by the Mission Integrator. For guidelines to derive qualification test levels and durations, consult GSFC-STD-7000A and SMC-S-016. The

flight model will then be tested to Acceptance levels in a Test 6U Dispenser then integrated into the flight 6U Dispenser for a final acceptance/workmanship random vibration test. **Additional testing may be required if modifications or changes are made to the CubeSats after qualification testing.**

4.5.2 Protoflight

Protoflight testing is performed on the flight model CubeSat. Protoflight levels will be determined by the Mission Integrator. For guidelines to derive protoflight test levels and durations, consult GSFC-STD-7000A and SMC-S-016. The flight model will be tested to Protoflight levels in a Test 6U Dispenser then integrated into the flight 6U Dispenser for a final acceptance/workmanship random vibration test. The flight CubeSat **SHALL NOT** be disassembled or modified after protoflight testing. Disassembly of hardware after protoflight testing will require the Developer to inform the Mission Integrator to determine the path forward. **Additional testing will be required if modifications or changes are made to the CubeSats after protoflight testing.**

4.5.3 Acceptance

After delivery and integration of the CubeSat into the 6U Dispenser, additional testing will be performed on the integrated system. This test ensures proper integration of the CubeSat into the 6U Dispenser. The 6U Dispenser Integrator will coordinate and perform acceptance testing. Acceptance test levels will be determined by the Mission Integrator. For guidelines to derive acceptance test levels and durations, consult GSFC-STD-7000A and SMC-S-016. The CubeSat **SHALL NOT** be de-integrated from the 6U Dispenser at this point. If a CubeSat failure is discovered, a decision to de-integrate the 6U Dispenser will be made by the Developers, in that 6U Dispenser, and the Mission Integrator based on safety concerns. The Developer is responsible for any additional testing required due to corrective modifications to de-integrated 6U Dispensers and CubeSats.

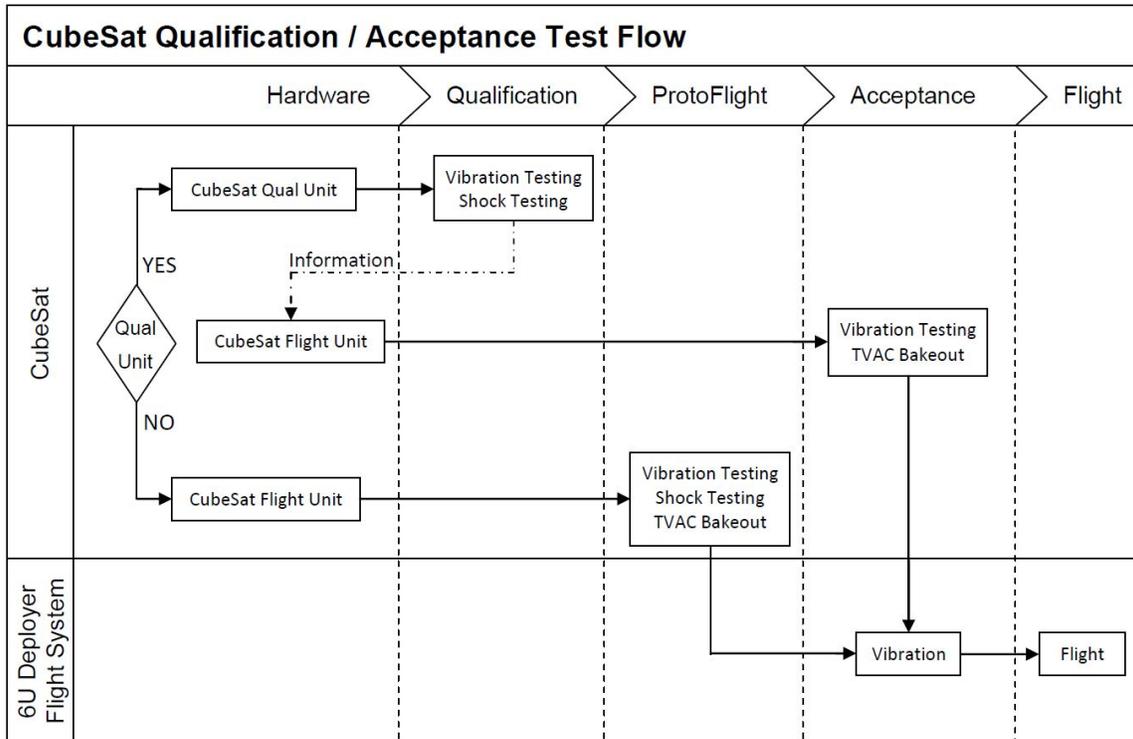


Figure 4: CubeSat General Testing Flow Diagram

Note: CubeSat test flows will vary from mission to mission; the Mission Integrator will provide the CubeSat Developer with the approved test flow for a specific mission.

5. Options

Dispenser specific options are available to support specific CubeSat mission requirements. Please contact the dispenser provider for details about any options prior to incorporating them into your 6U CubeSat design.

5.1 *ISIS 6-POD Dispenser*

The 6-POD dispenser was developed by ISIS, a small satellite company based in the Netherlands. Its design is derived from the 1U and 3U dispensers also available from ISIS.

5.2 *Planetary Systems Corporation Canisterized Satellite Dispenser*

The CSD was developed by Planetary Systems Corporation and is currently the only dispenser available that uses the tab system to constrain CubeSat payloads. Additional advantages of using the tab system include having an analyzable load path to the payload, and a flexible external payload shape.

5.3 *Tyvak Nanosatellite Launch Adapter System*

The Tyvak NLAS Mk. II design was derived from the NASA Ames Research Center NLAS Mk. I. The design incorporates lessons learned from the NLAS Mk. I and the Poly Picosatellite Orbital Deployer (P-POD) designs.

Options	6-POD ISIS www.isispace.nl	CSD Planetary Systems www.planetarysystemscorp.com	NLAS Tyvak www.tyvak.com
Access Ports		X	X
Additional Mass			X
Power/Data Port		X	X
Purge			X
X-Y Constraint	X	X	
Z Constraint	X	X	X
6U+ Additional Volume	X		X

Available Option Descriptions:

Access Ports	Access ports are used to physically access the satellite while the CubeSat is integrated within the 6U dispenser. The access ports allow the RBF pins to be removed post-integration into a 6U dispenser, and they can be used to visually verify separation switch engagement after the CubeSat has been integrated.
Additional Mass	Some dispensers have been designed to accommodate a larger payload mass than this document specifies. Please refer to the dispenser website for specific mass limits. The mass limits of a dispenser are dependent on the dynamic environments of a launch.
Power/Data Port	This option allows the CubeSat to electrically interface with the dispenser while integrated. For specific information regarding power-on capabilities, please refer to the dispenser website.
Gaseous Purge	This option allows the dispenser to be configured for gaseous purge throughout launch. For specific information regarding purge capabilities, please refer to the dispenser website.
X-Y Constraint	PSC utilizes long flat tabs, in lieu of rails, to which the dispenser applies a clamping pre-load. This constrains the CubeSat while integrated in the dispenser. CubeSats designed to a tab system specification may not be compatible with a rail-based 6U dispenser, and visa-versa. The ISIS 6-POD dispenser employs a constraint system that is compatible with the rail design. Please see the dispenser website for a full list of mechanical requirements associated with each constraint system.
Z Constraint	All current dispensers fully constrain the payload in the Z axis.
6U+ Additional Volume	Similar to the 3U+ extended volume available for 3U CubeSats, 6U+ offers a cylindrical volume extension on the $-Z$ face of the CubeSat. Contact the dispenser developer for further details.

6. Contacts

Cal Poly - San Luis Obispo

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Appendix A: Waiver Inquiry Request

CubeSat Design Specification Waiver Inquiry Request

Created on 15 June 2015

Date:

Name of request initiator:

Organization:

Contact Information:

Mission Name:

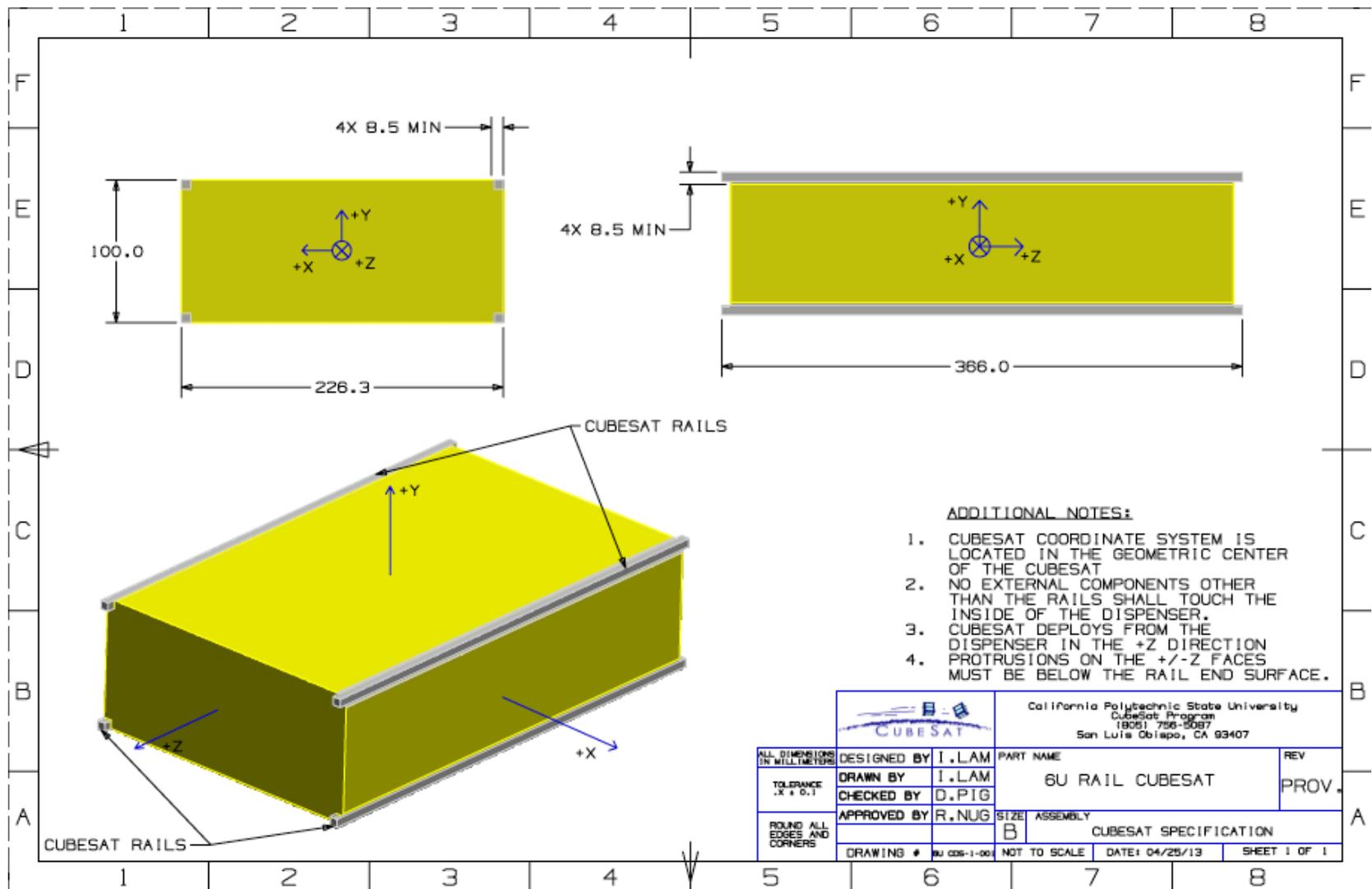
Brief CubeSat Description (size, mission goal, etc.):

Which are requirements not met?

Describe how the requirement will not be met.

Please explain how this deviation from the standard requirements will not present an added risk to the mission. Include pictures as necessary.

Appendix B: 6U CubeSat Specification Drawing



6U Rail CubeSat Design Specification Drawing with no options shown

The 6U Tab CubeSat Drawing can be found in the PSC payload document at

<http://www.planetarysys.com/web/wp-content/uploads/2014/08/2002367B-Payload-Spec-for-3U-6U-12U-27U.pdf>

Appendix C: 6U CubeSat Acceptance Checklist

