Document Classification	
X	Public Domain
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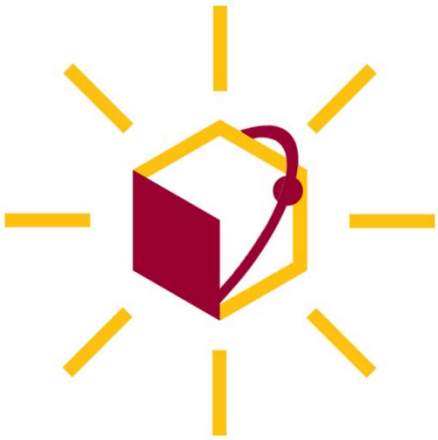


SunCube FemtoSat Design Specifications (SFDS)

Change History Log

Effective Date	Revision	Authors	Description of Changes
	1	Mercedes Martinez, Andrew Warren, Aman Chandra, Jekan Thanga	Creation of the document

List of Acronyms

AFSPCMAN	Air Force Space Command Manual
SFAC	SunCube FemtoSat Acceptance Checklist
Cal Poly	California Polytechnic State University, San Luis Obispo
SFDS	SunCube FemtoSat Design Specification
cm	Centimeters
CVCM	Collected Volatile Condensable Mass
DAR	Deviation Wavier Approval Request (CubeSat)
SDAR	SunCube Deviation Wavier Approval Request
FCC	Federal Communication Commission
GSFC	Goddard Space Flight Center
IARU	International Amateur Radio Union
kg	Kilogram
LSP	Launch Services Program
LV	Launch Vehicle
MIL	Military
Mm	Millimeters
NASA	National Aeronautics and Space Administration
NPR	NASA Procedural Requirements
P-POD	Poly Picosatellite Orbital Deployer
F-POD	FemtoSat Packager and Orbital Deployer
RBF	Remove Before Flight
Rev.	Revision
RF	Radio Frequency
ASU	Arizona State University
SSDL	Space Systems Development Lab
STD	Standard
TML	Total Mass Loss
µm	Micrometer

1.0 Applicable Documents

The following documents form a part of this document to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this document, the contents of this document shall take precedence.

- Cal Poly CubeSat Design Specifications Document (www.cubesat.org)
- LSP Program Level P-POD and CubeSat Requirements Document (LSP-REQ-317.01)
- General Environmental Verification Standard for GSFC Flight Programs and Projects (GSFC-STD-7000)
- Military Standard Test Requirements for Launch, Upper-stage, and Space Vehicles (MIL-STD-1540)
- Air Force Space Command Manual 91-710, Range Safety User Requirements Manual (AFSPCMAN 91-710)
- MIL Handbook - Material Properties (MIL-HDBK-5)
- Standard Materials and Processes Requirements for Spacecraft (NASA-STD-6016) NASA
- Procedural Requirements for Limiting Orbital Debris (NPR 8715.6)

2.0 Introduction

2.1 Overview

The SunCube FemtoSat project started as part of an internal research activity in 2014 is led by Prof. Jekan Thangavelautham and students at the Space and Terrestrial Robotic Exploration (SpaceTREx) Laboratory. The purpose is to utilize the latest in miniaturized electronics, sensors and actuators towards developing truly affordable, fully functioning spacecraft that can be rapidly launch into space in a matter of month. By reducing the launch costs, it is hoped a wider community of educators, researchers and hobbyists can develop their own spacecraft. The standard is targeted towards personal, scientific, private and government payloads. A SunCube FemtoSat consists of 1F which is a 3 cm cube with a mass of 35 grams and the 3F which is 9 cm x 3 cm x 3 cm and has a mass of 100 g. The deployer for a SunCube FemtoSat consists of a CubeSat. This enables the standard to be bootstrapped to the CubeSat standard enabling potential FemtoSat developers to tap into and utilize the knowledgebase present within the CubeSat community. If you are planning to start a SunCube FemtoSat project, please contact SpaceTREx at ASU. Visit the SunCube FemtoSat website at http://suncube.asu.edu for more information. The SunCube standard relies heavily upon the CubeSat standard but targets small devices.

Figure 1: SunCube FemtoSat in 1F and 3F configurations

2.2 Purpose

The primary mission of the SunCube FemtoSat Program is to provide access to space for small payloads. The primary responsibility of Arizona State University, as the developer of the FemtoSat Packager and Orbit Deployer (F-POD), is to ensure the safety of the CubeSat Deployer, (P-POD) and protect the launch vehicle (LV), primary payload, and other CubeSats. The F-POD is designed to be fully compatible with the Cal Poly CubeSat Standard. SunCube FemtoSat developers should play an active role in ensuring the safety and success of SunCube missions by implementing good engineering practice, testing, and verification of their systems.

Failures of FemtoSat, F-POD, the P-POD, or interface hardware can damage the LV or a primary payload and put the entire FemtoSat and CubeSat Program in jeopardy. As part of the small spacecraft

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 may be superseded by launch provider requirements.

2.3 Waiver Request Process

Spacecraft developers will fill out a "SunCube Deviation Waiver Approval Request (SDAR)" (see Appendix A) if their FemtoSat is in violation of any requirements in sections 2 or 3. The waiver process is intended to be quick and easy, but consist of several steps. This process provides communication and explicit documentation between the FemtoSat developers, F-POD developers, P-POD integrators, range safety personnel, and launch vehicle providers. Request for an SDAR may only impact or result in extra testing of the F-POD. However this may also trigger request for a DAR (Waiver Request to the CubeSat standard). The SDAR can be found at http://suncube.asu.edu/ and waiver requests should be sent to spacetrex@asu.edu.

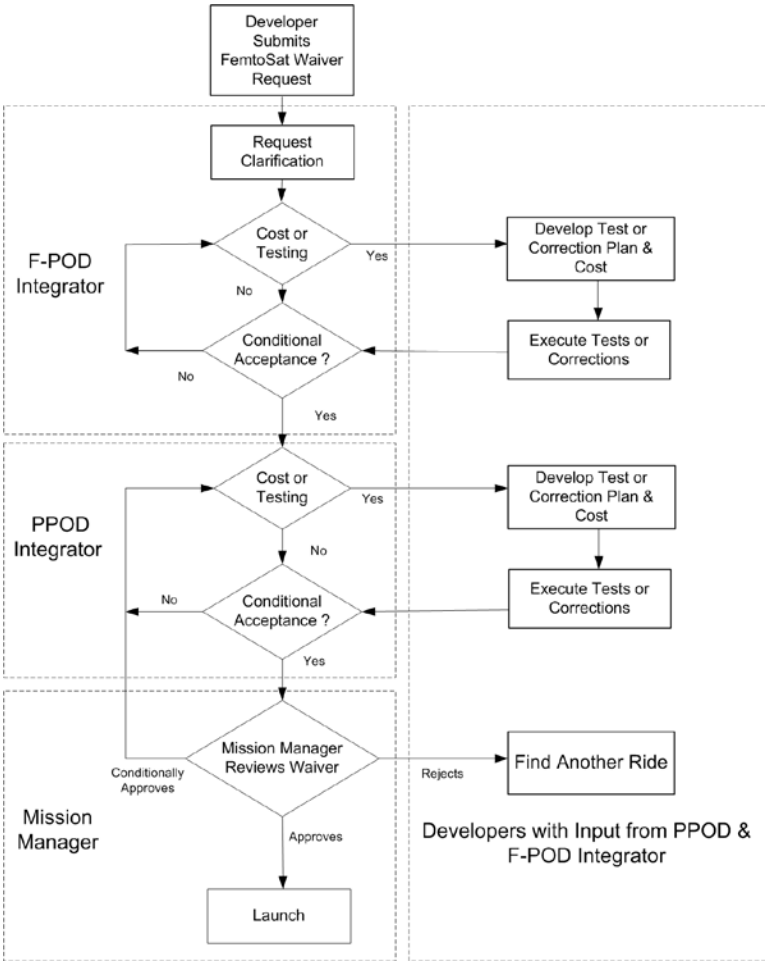


Figure 2: SunCube FemtoSat Standard Deviation Wavier Process Flow Diagram

Upon completion of the SDAR, the F-POD Integrator will fully review the request, resolve any questions and identify if additional testing, analysis or cost is incurred due to the requested waiver. If such work is required, then the spacecraft developer will need to develop a test plan with input from the F-POD Integrator and PPOD integrator. Then the developer needs to perform tests until it is conditionally

accepted by the F-POD Integrator. Waiver can only be accepted until a launch provider has been identified. Once a launch has been identified, the waiver becomes mission specific and passes to the launch vehicle Mission Manager for review. The Launch Vehicle Mission Manager (LVMM) has the final say on acceptance of the waiver, and may require more corrections and/or testing to be performed before approving the waiver. Developers should realize that each waiver submitted reduces the chances of finding a suitable launch opportunity.

3.0 FemtoSat Packager and Orbital Deployer (F-POD)

3.1 Interface

The SunCube uses the FemtoSat Packager and Orbital Deployer customized to integrate with the standardized CubeSat dimensions. A single deployer unit is capable of releasing 27 1Fs SunCube FemtoSats, 9 3F SunCube FemtoSats or some combination thereof at a time. The deployer unit, designed at Arizona State University's SpaceTREx Laboratory is compatible with the inner rails of standard 1U CubeSat.

To reduce deployment costs and ensure simplicity, a modified 1U cubesat with a "Jack in the box" spring release mechanism will release the FemtoSats. Hence, Femtosats can be carried as additional payload on regular CubeSat missions without the need of additional deployment mechanisms. Figure 3 illustrates the mechanism.

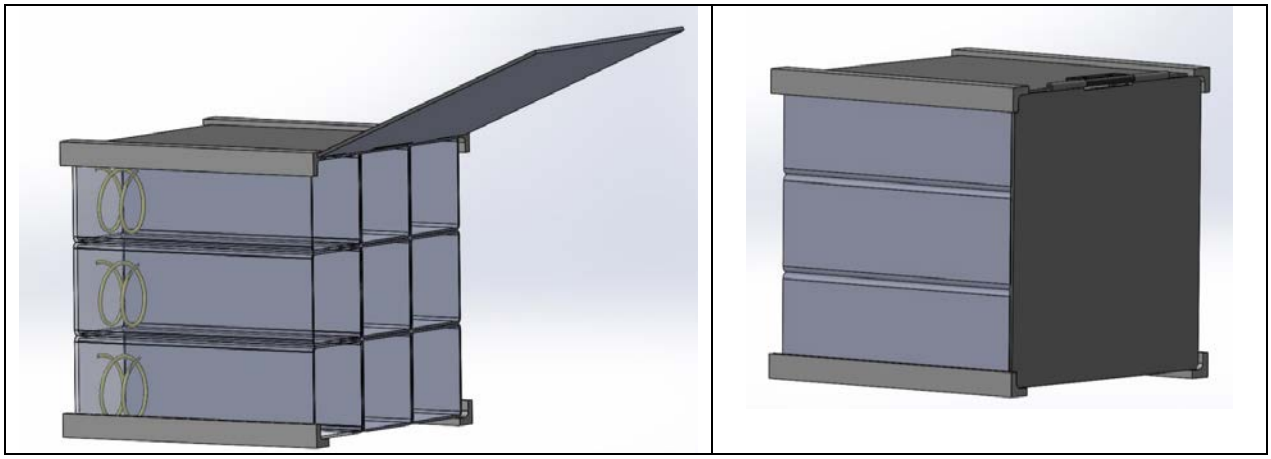


Figure 3: FemtoSat deployer single and multiple units

4.0 SunCube FemtoSat Specifications

4.1 General Requirements

4.1.1	SunCube FemtoSats which incorporate any deviation from the SFDS will submit a SDAR and adhere to the waiver process (see Section 2.3 and Appendix A).
4.1.2	All parts shall remain attached to the SunCube FemtoSats during launch, ejection and operation. No additional space debris will be created.
4.1.3	No pyrotechnics shall be permitted
4.1.4	Any propulsion systems shall be designed, integrated, and tested in accordance with AFSPCMAN 91-710 Volume 3
4.1.5	Propulsion systems shall have at least 3 inhibits to activation.
4.1.6	Total stored chemical energy will not exceed 30 Watt-Hours.
4.1.6.1	Note: Higher capacities may be permitted, but could potentially limit launch opportunities.
4.1.7	SunCube FemtoSat hazardous materials shall conform to AFSPCMAN 91-710, Volume 3.
4.1.8	SunCube FemtoSat 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
4.1.8.1	SunCube FemtoSats materials shall have a Total Mass Loss (TML) $\leq$ 1.0 %
4.1.8.2	SunCube FemtoSat materials shall have a Collected Volatile Condensable Material (CVCM) $\leq$ 0.1%
4.1.9	The latest revision of the SunCube FemtoSat Design Specification will be the official version which all FemtoSat developers will adhere to. The latest revision is available at http://suncube.asu.edu
4.1.9.1	ASU SpaceTREx will send updates to the SunCube FemtoSat mailing list upon any changes to the specification. You can get info on how to sign-up for the SunCube FemtoSat mailing list here: http://suncube.asu.edu
4.1.10	Note: Some launch vehicles hold requirements on magnetic field strength. Additionally, strong magnets can interfere with the separation between SunCube FemtoSat spacecraft in the same F-POD. As a general guideline, it is advised to limit magnetic field outside the SunCube FemtoSat static envelope to 0.5 Gauss above Earth's magnetic field
4.1.11	The SunCube FemtoSat shall be designed to accommodate ascent venting per ventable volume/area < 2000 inches.

4.2 SunCube FemtoSat Mechanical Requirements

SunCubes are cube shaped femtosatellites with dimensions and features outlined in the SunCube FemtoSat Specification Drawing (Appendix B). The PPOD coordinate system is shown below in Figure 4 for reference.

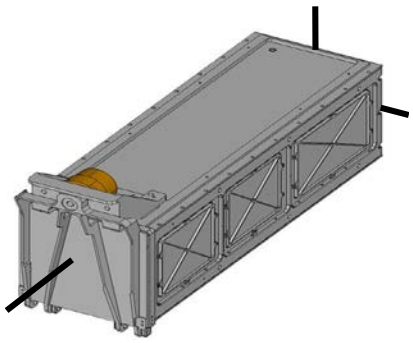


Figure 4: PPOD Coordinate System

General features of all SunCube FemtoSats include:

4.2.1	The SunCube FemtoSat shall use the coordinate system as defined in Appendix B for the appropriate size. The SunCube FemtoSat coordinate system will match the P-POD coordinate system while integrated into the F-POD. The origin of the SunCube FemtoSat coordinate system is located at the geometric center of the SunCube FemtoSat.
4.2.1.1	The SunCube FemtoSat configuration and physical dimensions shall be per the appropriate section of Appendix B.
4.2.2	The –Z face of the SunCube FemtoSat will be inserted first into the F-POD.
4.2.3	No components on the green and yellow shaded sides shall exceed 2.0 mm normal to the surface.
4.2.3.1	When completing a SunCube FemtoSat Acceptance Checklist (FAC), protrusions will be measured from the plane of the rails.
4.2.4	Deployables shall be constrained by the SunCube FemtoSat, not the F-POD.
4.2.5	Rails shall have a minimum width of 2mm.
4.2.6	Rails will have a surface roughness less than 1.0 µm.
4.2.7	The edges of the rails will be rounded to a radius of at least 1 mm
4.2.8	The ends of the rails on the +/- Z face shall have a minimum surface area of 1.5 mm x 1.5 mm contact area for neighboring SunCube FemtoSat rails (as per Figure 5).
4.2.9	At least 75% of the rail will be in contact with the F-POD rails. 25% of the rails may be recessed and no part of the rails will exceed the specification.
4.2.10	The maximum mass of a 1F SunCube FemtoSat shall be 0.035 kg.
4.2.10.1	Note: Larger masses may be evaluated on a mission to mission basis.
4.2.11	The maximum mass of a 3F SunCube FemtoSat shall be 0.100 kg
4.1.11.1	Note: Larger masses may be evaluated on a mission to mission basis.
4.1.12	The SunCube FemtoSat center of gravity shall be located within 0.6 cm from its

geometric center in the X and Y direction.

4.1.12.1 The 1F SunCube FemtoSat center of gravity shall be located within 0.6 cm from its geometric center in the Z direction.

4.1.12.2 The 2F SunCube FemtoSat center of gravity shall be located within 1.5 cm from its geometric center in the Z direction.

4.1.12.3 The 3F SunCube FemtoSat center of gravity shall be located within 2.3 cm from its geometric center in the Z direction.

4.1.13 Aluminum 7075, 6061, 5005, and/or 5052 will be used for both the main SunCube FemtoSat structure and the rails.

4.1.13.1 If other materials are used the developer will submit a SDAR and adhere to the waiver process.

4.1.14 The SunCube FemtoSat rails and standoff, which contact the F-POD rails and adjacent FemtoSat standoffs, shall be hard anodized aluminum to prevent any cold welding within the F- POD.

4.1.15 The 1F and the 3F SunCube FemtoSats shall use separation springs to ensure adequate separation.

4.1.15.1 The compressed separation springs shall be at or below the level of the standoff.

4.1.15.2 The 1F and 3F SunCube FemtoSat separation spring will be centered on the end of the standoff on the SunCube FemtoSat's –Z face as per Figure 5.

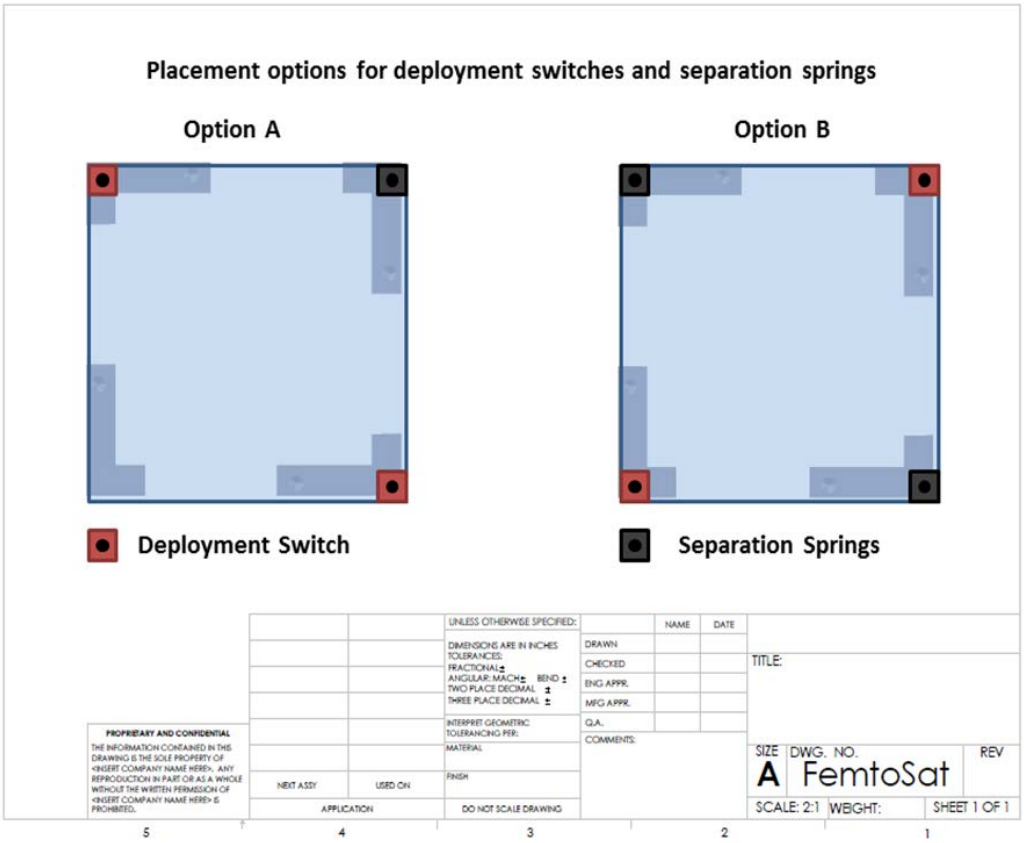


Figure 5: Deployment Switches and Separation Spring Locations

4.3 SunCube FemtoSat Electrical Requirements

4.3.1 No electrical systems may be energized from launch until deployment in order to prevent interference of any kind with the launch vehicle.

4.3.2 All SunCube FemotSats must have at least one deployment switch that will completely power off the satellite when activated

4.3.3 All umbilical connections must be made on the +X and –X faces.

4.3.4 A SunCube FemtoSat shall include a remove before flight (RBF) pin or launch with fully discharged batteries.

4.3.4.1 The RBF pin must be located on the + or – X faces.

4.3.4.2 The RBF pin shall cut all power to the satellite.

4.3.4.3 The RBF pin shall not protrude more than 3 mm from the rails when fully inserted.

4.4 SunCube FemtoSat Operational Requirements

SunCube FemtoSats will meet certain requirements pertaining to integration and operation to meet legal obligations and ensure safety of other spacecraft.

4.4.1 SunCube FemtoSats with batteries shall have the ability to receive a transmitter shutdown command as per Federal Communications Commission (FCC) requirements.

4.4.2 Operators will obtain and provide documentation of proper licenses for use of radio frequencies.

4.4.3 Deployables must wait a minimum five minutes from the release of the deployment switch to activate.

4.4.4 RF transmitters greater than 1mW must wait a minimum of five minutes from the release of the deployment switch before activating.

4.4.5 Operators shall obtain and provide documentation of proper licenses for use of any used frequencies

4.4.6 Orbital decay lifetime shall be less than twenty five years after the end of the mission

4.4.7 A minimum of one fit check must be performed to ensure proper integration into the deployment mechanism before launch.

4.4.8 The SunCube FemtoSat acceptance checklist (Appendix C) will be used to verify compliance with the outlined specifications.

5. Testing Requirements

Testing will be performed to meet all launch provider requirements and meet the safety requirements of the F-POD, P-POD, and the primary mission. If the launch vehicle environment is unknown, The General Environmental Verification Standard (GEVS, GSFC-STD-7000) and MIL-STD-1540 can be used to derive testing requirements. GSFC-STD-7000 and MIL-STD-1540 are excellent references when defining testing environments and requirements; however the test levels defined in GSFC-STD-7000 and MIL-STD-1540 are not guaranteed to cover all LV testing environments. Refer to the launch provider's payload integration manual.

Test requirements and levels that are not generated by the launch provider, P-POD or F-POD Integrator are unofficial. The launch provider testing requirements will supersede testing environments from any other source. The P-POD will be tested in a similar fashion to ensure the safety and workmanship before integration with the F-POD. At the very minimum, all SunCube FemtoSats will undergo the following tests.

5.1 Random Vibration

Random vibration testing shall be performed as defined by the launch provider

5.2 Thermal Vacuum Bakeout

Thermal vacuum bakeout shall be performed to ensure proper outgassing of components. The test specification will be outlined by the launch provider.

5.3 Shock Testing

Shock testing shall be performed as defined by the launch provider.

5.4 Visual Inspection

A visual inspection will be performed of the FemtoSat and of critical areas as appropriate.

5.5 CubeSat Testing Philosophy

The SunCube FemtoSat shall be subjected to either a qualification or protoflight testing as defined in the SunCube Testing Flow Diagram, shown in Figure 7. The test levels and durations will be supplied by the launch provider or P-POD integrator.

5.5.1 Qualification

Qualification testing is performed on an engineering unit hardware that is identical to the flight model SunCube FemtoSat. Qualification levels will be determined by the launch vehicle provider or P-POD integrator. Both MIL-STD-1540 and LSP-REQ-317.01 are used as guides in determining testing levels. The flight model will then be tested to Acceptance levels in a TestPOD then integrated into the flight P-POD for a final acceptance/workmanship random vibration test. Additional testing may be required if modifications or changes are made to the SunCube FemtoSat after qualification testing.

5.5.2 Protoflight

Protoflight testing is performed on the flight model SunCube FemtoSat. Protoflight levels will be determined by the launch vehicle provider or P-POD integrator. Both MIL-STD-1540 and LSP-REQ-317.01 are used as guides in determining testing levels. The flight model will be tested to Protoflight levels in a Test P-POD and F-POD then integrated into the flight F-POD and P-POD for a final acceptance/workmanship random vibration test. The flight SunCube FemtoSat SHALL NOT be disassembled or modified after protoflight testing. Disassembly of hardware after protoflight testing will require the developer to submit a DAR and adhere to the waiver process prior to disassembly. Additional testing will be required if modifications or changes are made to the SunCube FemtoSat after protoflight testing.

5.5.3 Acceptance

After delivery and integration of the SunCube FemtoSat into the F-POD and into the P-POD, additional testing will be performed with the integrated system. This test ensures proper integration of the F-POD into the P-POD. Additionally, any unknown, harmful interactions between CubeSats may be discovered during acceptance testing. The P-POD and F-POD Integrators will coordinate and perform acceptance testing. Acceptance levels will be determined by the launch vehicle provider or P-POD integrator. Both MIL-STD-1540 and LSP-REQ-317.01 are used as guides in determining testing levels. The P-POD and F-POD SHALL NOT be deintegrated at this point. If a SunCube FemtoSat failure is discovered, a decision to deintegrate the P-POD and/or F-POD will be made by the developers based on safety concerns. The developer is responsible for any additional testing required due to corrective modifications to deintegrated P-PODs and F-PODs.

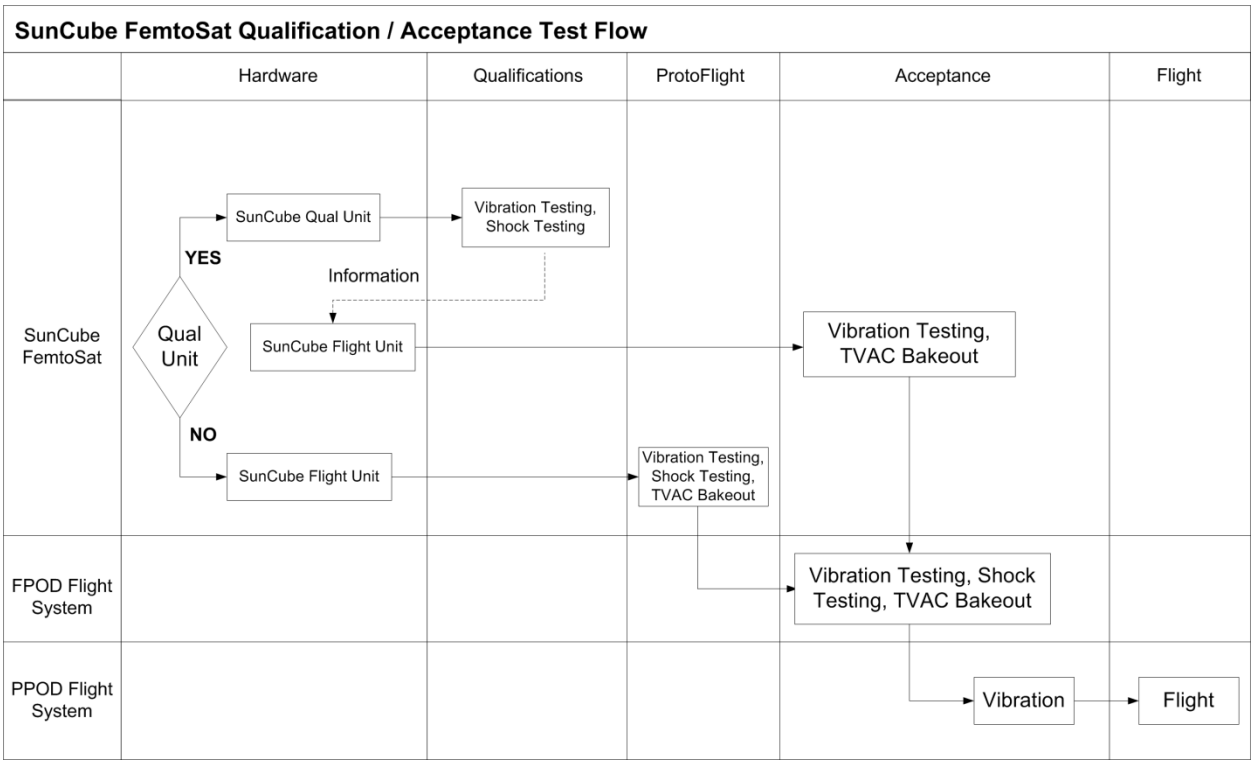


Figure 7: SunCube FemtoSat General Testing Flow Diagram

6.0 Contacts

Arizona State University

Jekan Thangavelautham
Space and Terrestrial Robotic
Exploration (SpaceTREx) Laboratory
School of Earth and Space Exploration

Phone: (480) 727-2218
Fax: (480) 965-5081
Email: jekan@asu.edu

Arizona State University Student Contact

Phone: (480) 727-2236
Email: spctrex@asu.edu

Appendix A: Waiver Form

SunCube FemtoSat Design Specification
Deviation Waiver Approval Request (SDAR)

Date: April 7, 2016, Rev 1

SunCube FemtoSat Developers only fill out sections 1 through 9 and 15(optional). Email to: spacetrex@asu.edu

1. MISSION NAME:	2. SDAR NUMBER:	3. DATE:
4. INITATOR	5. INITIATING ORGANIZATION:	

6. SPECIFIED REQUIREMENTS NUMBERS:	7. JUSTIFICATION FOR DAR:	8. WAIVER TYPE ☐ DIMENSIONS or MASS ☐ STRUCTURE ☐ ELECTRICAL ☐ OPERATIONS ☐ TESTING ☐ OTHER

9. DESCRIPTION OF DEPARTURE FROM REQUIREMENTS:

10. CSEP DISPOSITION:
☐ ACCEPTED
☐ REJECTED
☐ CONDITIONALLY ACCEPTED

11. ACCEPT/REJECT JUSTIFICATION:

CSEP AUTHORIZED REP.	SIGNATURE	ORGANIZATION	DATE

12. ACCEPTANCE CONDITIONS

13. CUBESAT CONTAINER INTEGRATOR APPROVAL AUTHORITY:
☐ APPROVED
☐ DISAPPROVED
☐ CONDITIONALLY APPROVED

14. CCIAA APPROVAL/DISAPPROVAL JUSTIFICATION:

CCIAA AUTHORIZED REP.	SIGNATURE	ORGANIZATION	DATE

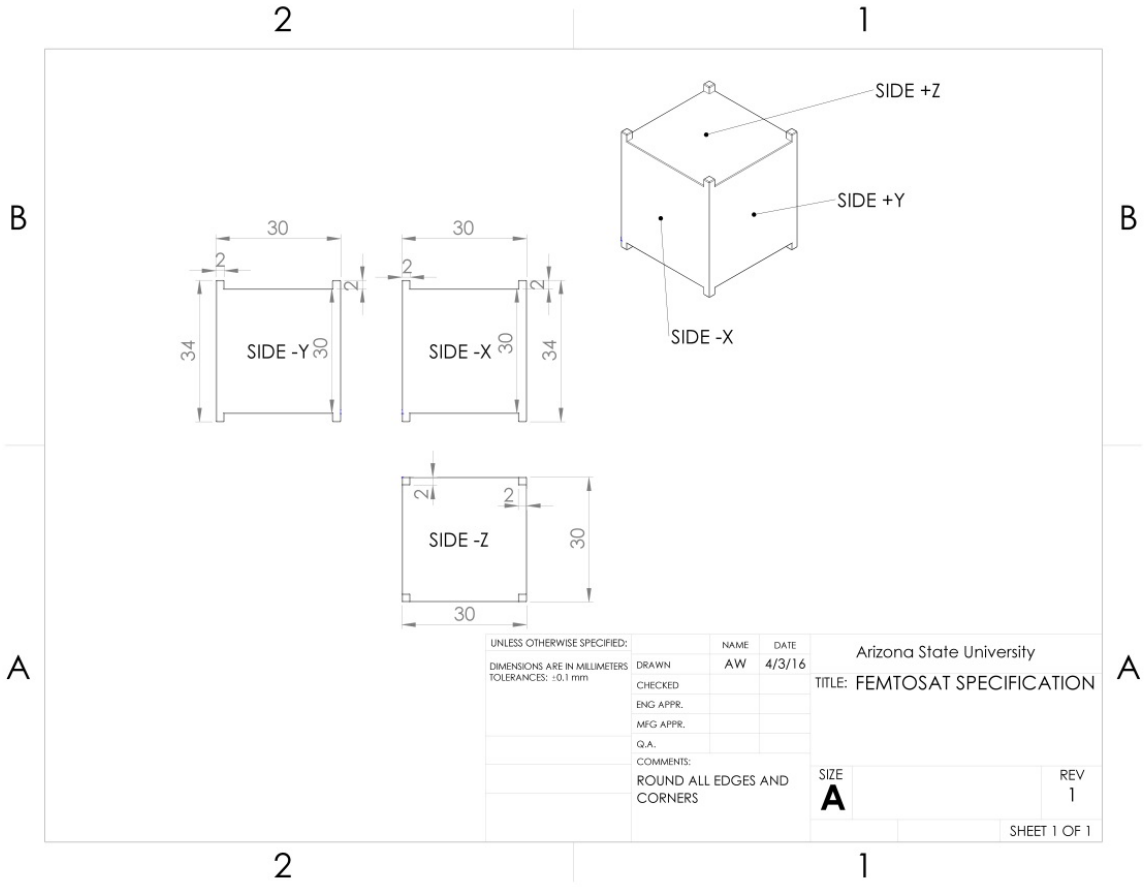
15. APPROVAL CONDITIONS

1. MISSION NAME:	DEVIATION WAIVER APPROVAL REQUEST CONTINUATION PAGE	2. SDAR NO.	3. DATE:

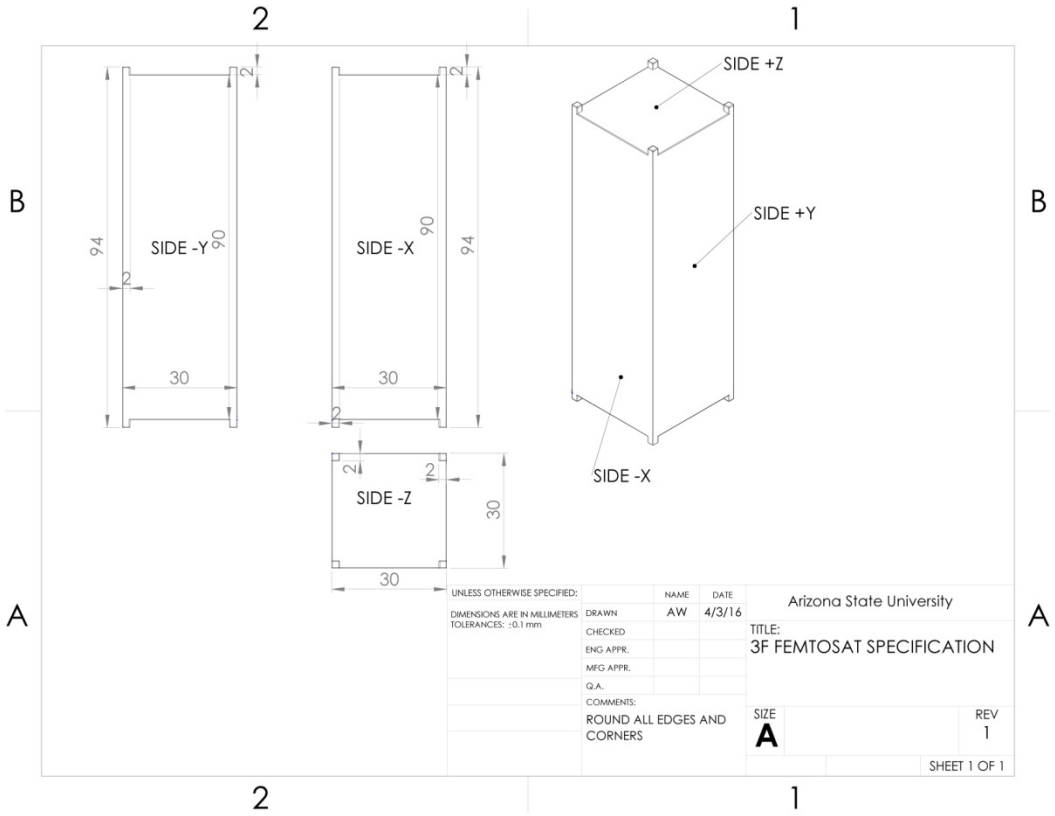
16. CONTINUATION (indicate item or block number):

Appendix B: 1F and 3F SunCube FemtoSat Specification Drawings

Section 1
1F SunCube FemtoSat Design Specification Drawing



Section 2
3F SunCube FemtoSat Design Specifications Drawing



Section 1
1F SunCube FemtoSat Acceptance Checklist

1F SunCube FemtoSat Acceptance Checklist

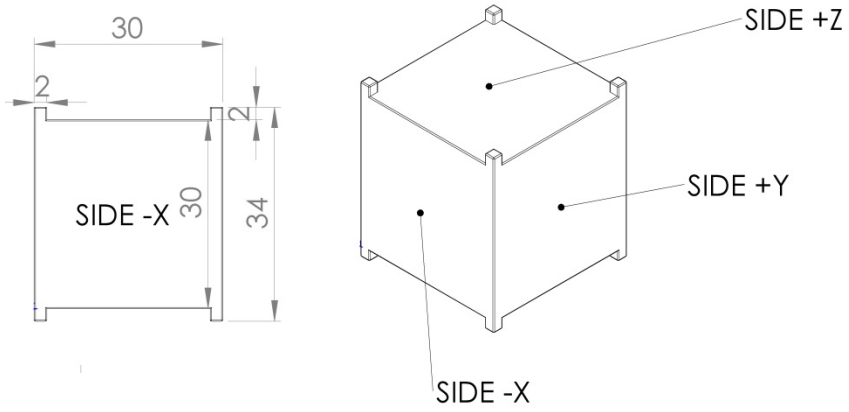
Project: Date/Time: Engineers:

Organization: Location:

Satellite Name: Satellite S/N: Revision Date: 04/03/2016

Mass (<0.035 kg)	--	**RBF Pin** (≤ 2mm)	--
Spring Plungers (Depressed)	Functional Y/N Flush with Standoff Y/N	**Rails Anodized**	Y/N
Deployment Switches (Depressed)	Functional Y/N Flush with Standoff Y/N	**Deployables Constrained**	Y/N

Mark on the diagram the locations of the RBF pin, connectors, deployables, and any envelope violations.



Authorized By:

IT #1: _____

IT #2: _____

Passed: **Y** / **N**

List Item	As Measured						Required
Width [x – y]	Side 1(-Y)		Side 2 (-X)		Side 3 (+Y)	Side 4(+X)	
+Z	----------		----------		----------	----------	30.0 ± 0.02mm
Middle	----------		----------		----------	----------	30.0 ± 0.02mm
-Z	----------		----------		----------	----------	30.0 ± 0.02mm
Heights [x-y]	Rail 1 (+X,-Y)		Rail 2 (-X, -Y)		Rail 3 (-X, +Y)	Rail 4 (+X,+Y)	
	----------		----------		----------	----------	34.0 ± 0.02mm
	Rail 1 (+X,-Y)		Rail 2 (-X, -Y)		Rail 3 (-X, +Y)	Rail 4 (+X,+Y)	
+Z Standoffs	____X ____		____X ____		____X ____	____X ____	≥ 2.0 mm
-Z Standoffs	____X ____		____X ____		____X ____	____X ____	≥ 2.0 mm
Protrusions	Side 1 (-Y)	Side 2 (-X)	Side 3 (+Y)	Side 4 (+X)	Side 5 (-Z)	Side 6 (+Z)	≤ 2mm

Section 3
3F SunCube FemtoSat Acceptance Checklist

3F SunCube FemtoSat Acceptance Checklist

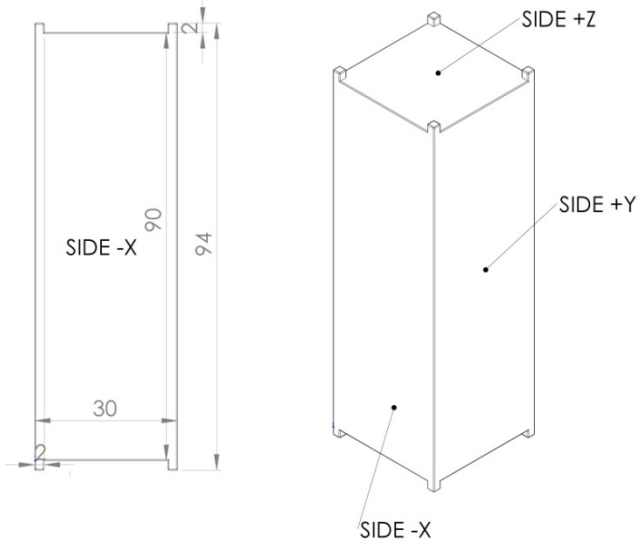
Project: Date/Time: Engineers:

Organization: Location:

Satellite Name: Satellite S/N: Revision Date: 04/03/2016

Mass (<0.100 kg)	--	**RBF Pin** (≤ 2mm)	--
Spring Plungers (Depressed)	Functional Y/N Flush with Standoff Y/N	**Rails Anodized**	Y/N
Deployment Switches (Depressed)	Functional Y/N Flush with Standoff Y/N	**Deployables Constrained**	Y/N

Mark on the diagram the locations of the RBF pin, connectors, deployables, and any envelope violations.



Authorized By:

IT #1: _____

IT #2: _____

Passed: **Y / N**

List Item	As Measured						Required
Width [x – y]	Side 1(-Y)		Side 2 (-X)		Side 3 (+Y)	Side 4(+X)	
+Z	----------		----------		----------	----------	30.0 ± 0.02mm
Middle	----------		----------		----------	----------	30.0 ± 0.02mm
-Z	----------		----------		----------	----------	30.0 ± 0.02mm
Heights [x-y]	Rail 1 (+X,-Y)		Rail 2 (-X, -Y)		Rail 3 (-X, +Y)	Rail 4 (+X,+Y)	
	----------		----------		----------	----------	94.0 ± 0.02mm
	Rail 1 (+X,-Y)		Rail 2 (-X, -Y)		Rail 3 (-X, +Y)	Rail 4 (+X,+Y)	
+Z Standoffs	____X ____		____X ____		____X ____	____X ____	≥ 2.0 mm
-Z Standoffs	____X ____		____X ____		____X ____	____X ____	≥ 2.0 mm
Protrusions	Side 1 (-Y)	Side 2 (-X)	Side 3 (+Y)	Side 4 (+X)	Side 5 (-Z)	Side 6 (+Z)	≤ 2mm