ODAR: EdgeCube – Sonoma State University – 1U CubeSat
Date: May 12, 2018

Full USIP Title: **EdgeCube: A 1U Global Monitor for Earth's Ecosystems**

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Mission Overview: EdgeCube will make a global measurement of the red edge that monitors a sharp change in leaf reflectance in the range 600 to 800 nm from changes in vegetation chlorophyll absorption and mesophyll scattering due to seasonal leaf phenology or stress. EdgeCube has been specifically designed to monitor the red edge characteristics of ~200 km areas of the earth using 9 narrow spectral bands in the wavelength range 600-800 nm. Two additional sensors will be flown: one will measure the optical and Infrared broadband signal in order to measure the incoming solar radiance. The incoming solar radiance is needed in order to calculate the top-of-atmosphere reflectance (at-sensor radiance/incoming solar radiance), thus normalizing the data through the seasons and by latitude. Although EdgeCube's ground spatial resolution is substantially less than conventional multispectral satellites, its design will monitor changes in the red-edge on a global scale within the telemetry limitations of a cubesat.

Mission requirements and goals:

(R1) Demonstrate mapping of a large fraction of the globe (+-50 degrees latitude) in Near IR to measure Red Edge and NDVI at a resolution of 100-300 km.
(R2) Minimum Requirement for Success: Global map of Red Edge from an initial two week period and thereby prove that the concept of EdgeCube works
(R3) Stretch Goal: operate EdgeCube for >2 years to monitor seasonal changes and year to year changes.
(R4) Map the Normal Optical Colors (RGB) of the Earth's surface to identify ocean/continent boundaries
(R5) Required Spectral Coverage (NIR - 9 narrow bands near red edge of chlorophyll - 1.3 micron for Cirrus cloud detection; and Optical – Red, Green and Blue for pointing)

(R6) After the fact pointing accuracy (<3 degrees using 3-axis magnetometer, gyroscope and Sub sensor). Stretch Goal: develop Star Tracker with ~0.1 degree accuracy to verify attitude determination for a sample of pointing.
(R7) Telemetry: ~500 bits per second for two 6-minute passes per day. Stretch Goal: ~5000 bits per second for two 6-minute passes per day.
(R8) Power: 0.25 watts orbit averaged including S/C night time. Brief Overview: Describe the satellite and mission objectives.

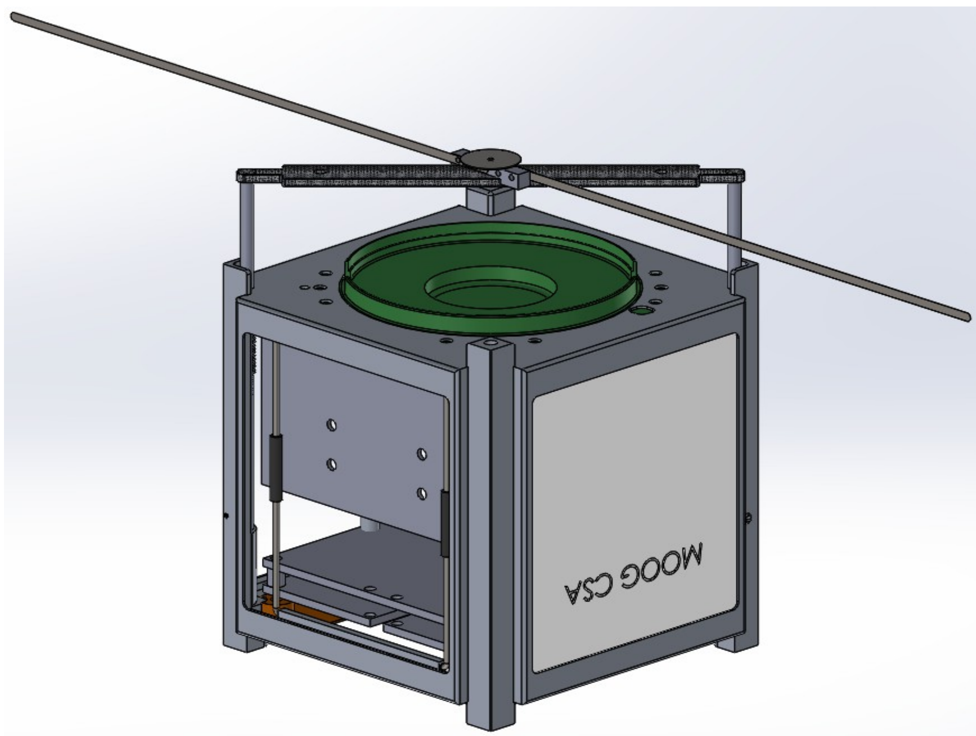


Figure 1: Outside view of the 1U CubeSat with the pop up antenna in the deployed configuration. The 1U body is 3D printed in Al in three major pieces. The main 1U body has four open window frames that house the three solar panels (82 mm x 85 mm). The four face house the sensors that built on a frame made of Dalrin that is exactly the same size as one of the solar panels. The top of the S/C is also printed In Al and has a mechanism to house the stowed antenna (enclosure shown on green). The bar below the antenna is also machined from Dalrin. This bar pops up and releases the curled up antenna which deploys and forms a dipole antenna (17 cm from tip to tip as needed for a RF frequency of ~437 MHz). The antenna is made of spring steel.

Figure 2: Shows the electronics boards that fill the interior of the 1U box. These image are all shown to approximately the same scale. All boards are either 4 cm x 8 cm or 8 cm x 8 cm. The board on the lower right is the RF system is that carries the RFM22B and RFM23BP transceivers. The upper left image shows the science sensors which occupy one face of the 1U and is the same size as the solar panel (1 of 3) that occupy the other three faces. The upper middle and right shows two views of the science sensor electronics connected to the sensor face made of Dalrin with viewing ports for the science sensors. The sensors on the upper left are not seen because these are behind the collimators. The larger hole in the middle of the sensor face is a viewing port for a camera that images both the Earth and stars to verify attitude of the S/C. The middle lower panel shows the power system and the flight NiCd batteries which also has the electronics for the safe mode of the S/C. If the battery voltage drops to a marginal low level the safe mode turns the system off for 2 hours so that the batteries have a full daylight cycle to recharge.

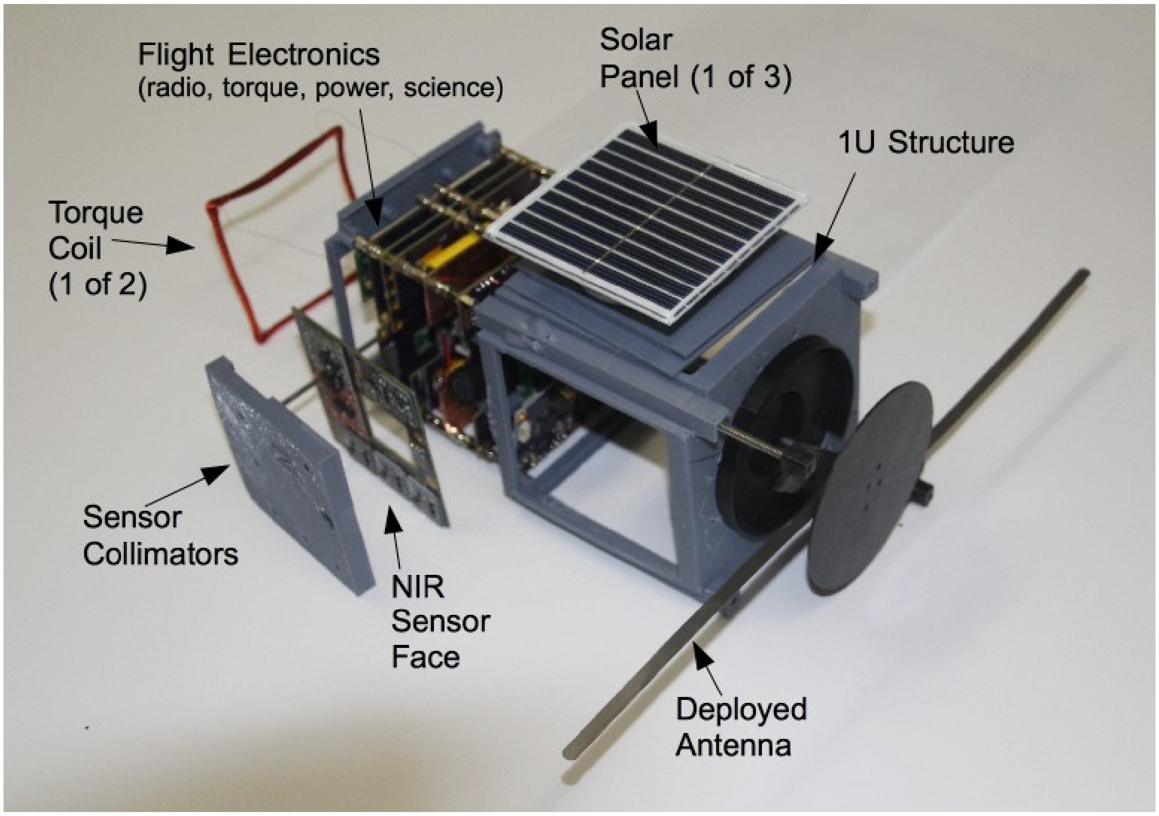


Figure 3: Shows a partially exploded view of the the stack of electronic boards that fill the interior of the 1U box. The bolts in the four corners are grounded to the 1U metal frame and also server to ground all the electronic boards in the stack. These means that the electronic grounding system does not require any cables except for the ground leads to the solar panels. The four grounding rods form the 8 cm x 8 cm x 8 cm structure that terminates at the top and bottom plates that are 3D printed in aluminum. The three NiCd batteries are the most massive components and are placed near the center of the mass of the system. This helps define the principal rotation axis as vertical in the image so that the sensors face scans over the Earth for every rotation of the 1U body. The fields of view of the sensors are set so that all parts of the Sun lite Earth are scanned once a day during the ~15 orbits.

CONOPS: EdgeCube is mounted in the launch dispenser with the antenna stowed on the outside of the top of the S/C in a thin aluminum canister. There are two retention pins that slide along two of the four launch rails on opposite sides that releases the pop up mechanism for the antenna as the 1U enclosure is half way out of the dispenser. The pins are captured to the 1U body after the CubeSat leaves the dispenser and are not released from the 1U body. No part of EdgeCube ever detaches from the system during normal operation prior to break up during re-entry.

Two series inhibit micro-switches on the top face of the S/C are activated by the popup mechanism which connects battery power to the electronics system. We have designed the power system so that during initial turn on the S/C goes into safe mode for ~2 hours to fully charge the NiCd batteries. The selection of NiCd batteries ensures that if we are left in the rocket for an extended period (many months) we will charge the batteries during one full day light cycle (~1.6 hours).

The system then exits safe mode and powers up the S/C processor that operates the RF system. The system can tell that this is the initial startup and then waits an additional 30 minutes before any RF transmission. This approach ensures that if the safe mode fails in a way that causes an early termination of safe mode then the processor will wait an additional 30 minutes to meet the requirement of at least 30 minutes before any RF transmission. The expected normal operation will wait 2.5 hours before any RF transmission.

Once the 30 minutes wait is over the S/C begins beacon transmissions every ~31 seconds. These beacon packets have sufficient information to determine the health of the power system. Once the ground system confirms the safe state of the flight electronics then science operations can proceed. The torque system will regulate the spin rate and point the spin axis within ~30 degrees of the NS direction. As the S/C rotates once every ~5-10 seconds the science sensor will scan a portion of the Earth under the S/C orbit path and record the NIR sensor reading in the form of packets that can be commanded for download when the S/C passes over the ground station on the roof of the student center at SSU. These data can then we used to compute a map of the globe of chlorophyll on a ~200 km scale every few days.

After the orbits lowers sufficiently due to atmospheric drag (years after launch) the S/C will break up and re-enter the Earth's atmosphere.

Materials:

The total mass of the S/C is 1.39 kg. The center of mass of the system is located within ~2 mm of the geometric center of the 1U electronics box. The total mass and center of mass can be easily adjusted because there is a central mass belt made of copper that helps retain and cool the solar panels and increases the moment of inertia about the spin axis to improve spin stability. The shape and mass of this thin copper belt near the central outer edge of the cubesat contacting the back of the solar panels can be easily adjusted because the mass allocation for the belt is ~500 g which is about 1/3 of the total mass. If any other element of the system is heaver than expected we can reduce the weight of the copper belt to keep the entire system under the weight limit.

The moment of inertia is estimated as:

$I_z = 2408$ kg cm^2 Note: Z is the spin axis.
$I_x = 2062$ kg cm^2
$I_y = 2055$ kg cm^2 Note: X and Y are the principle axises normal to the spin axis. These axes are nearly degenerate as expected.

All off-principle axis terms of the moment of inertia are <6 kg cm^2

Summary of materials:

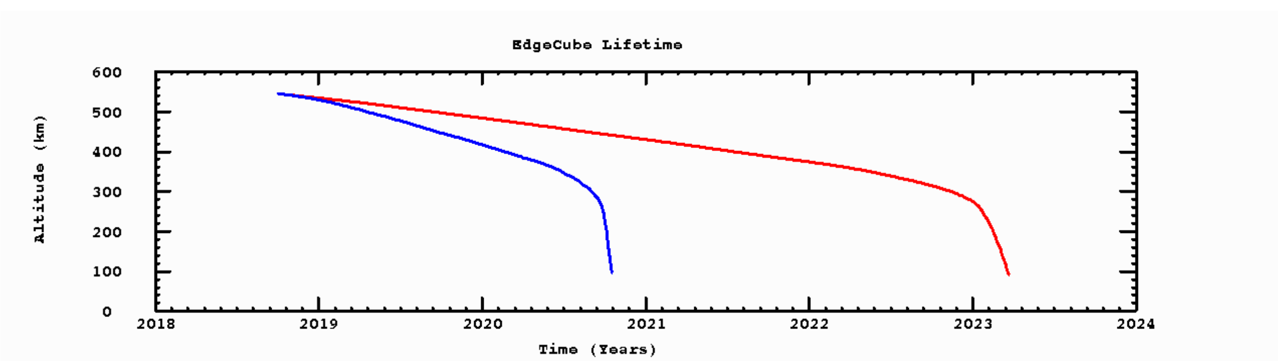
* Copper central mass belt	<500 g
* 1U body in the Al frame and the top and bottom Al structure	270 g
* Entire electronic board stack without the NiCd batteries	380 g
* Three NiCd batteries (each 50 g)	150 g
* Three Solar panels (each 56 g)	168 g
* Sensor Collimators (Dalrin)	50 g
* Dipole Antenna (spring steel)	10 g
* Dipole Antenna support structure (Dalrin)	20 g
* Magnet wire for two torque coils (each 10 g)	20 g
* Small amount of flight qualified wire	20 g
* ,Small amounts of low outgassing flight epoxy	10 g
Total Mass:	<1.39 kg

Hazards: There are no pressure vessels, hazardous or exotic materials. There are no hazardous systems on the satellite.

Batteries: We use three NiCd batteries similar to the ones flown on a previous successful mission (see URL http://lbym.sonoma.edu/T-LogoQube). Similar batteries were also flown on NASA HETE2 mission. These type of batteries are often used in heavy duty power tools because of safety and robustness. NiCd batteries can be safely discharged to zero and then recharged many times. We will test the specific flight batteries in vacuum with the spacecraft turned on to determine if the heat generated by use will cause any problems. This test is entirely independent of the required bakeout vacuum test. We do not expect any problems based on the prior use of NiCd batteries on orbit. NiCd batteries are lower energy density than any Lithium batteries and are known to be safer. Our 1U CubeSat is power limited by the solar panels and not by the NiCd batteries. We do not require Lithium batteries for normal operation.

EdgeCube Lifetime

The curve below shows a numerical simulation of the lifetime of the EdgeCube orbit. The initial height of the circular orbit is 545 km. These predictions are precise since the model is calibrated by the actual data for several 1U CubeSat for the full lifetimes as measured by the TLE database provided by the air force. The major uncertainty in the estimates of orbital lifetime is due to the uncertainty in the variation in the drag as a function of solar activity. The blue curve below assume a 3X above normal solar activity. The red curve assume a 3X reduced solar activity. Such extreme variations in solar activity are common and can not be reliably predicted for the future. The results are consistent with a range of orbital lifetimes of ~2 to ~5 years as shown in the figure below. The time axis of the figure is plotted assuming a nominal launch on Oct 1, 2018 (2018.75 years). The lifetime of a 1U CubeSat such as EdgeCube is sufficiently short so as not to require any special de-orbit measures. The largest items that would result from the re-entry breakup are three ~160 g pieces of copper that act as a mass belt around the middle of the S/C to help with spin stabilization of the S/C during normal operation. These largest components are not expected to survive reentry and impact the Earth's surface.



EdgeCube

ELaNa CubeSat ODAR Template, Rev. 2.0, 9/25/17

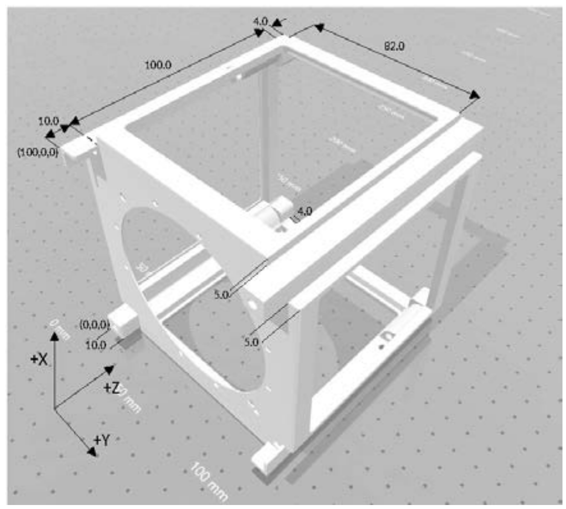
Row Number	Name	External/Internal (Major/Minor Components)	Qty	Material	Body Type	Unit Mass (g)	Total Mass (g)	Diameter/ Width (mm)	Length (mm)	Height (mm)
1	EdgeCube 1U Structure	External – Major	1	Aluminum (3D)	Box	270	270	100	100	100
2	Solar Panels	External - Major	3	Glass – Si	Rectangular	62.5	187.5	85	80	5
3	Battery	Internal – Major	3	NiCd	AA	20.3	60.6	48.5	14.5	14.4
4	NIR Collimators	External - Major	1	Dalrin + electronics	Rectangular	30	30	77.5	75	9.5
5	Primary Mounting Rods	Internal – Minor	4	Steel 4-40 Threads	Rod	3.6	14.4	2.7	100	2.7
6	Secondary Mounting Rods	Internal – Major	10	Steel 4-40 Threads	Rod	3	30	2.7	85.2	2.7
7	4-40 Nuts	Internal - Major	200	Steel 4-40 Threads	Nut	0.5	100	4.7	5.3	5
8	Power Board	Internal – Major	1	Electronics	Rectangular	16.6	16.6	85	40	7.5
9	S/C Monitor	Internal – Major	1	Electronics	Rectangular	24.4	24.4	85	40	13
10	Sensor Controller	Internal – Major	1	Electronics	Rectangular	24.8	24.8	85	40	13
11	Sensor Face	External – Major	1	Electronics	Rectangular	27.9	27.9	77.5	75	7.5
12	Torque Board	Internal – Major	1	Electronics	Rectangular	38.9	38.9	85	85	15
13	Battery Board	Internal – Major (no batteries)	1	Electronics	Rectangular	33.4	33.4	85	85	16.5
14	Copper Plate	Internal – Major	1	Copper alloy	Rectangular	200	200	85	85	4.5
15	S/C Controlled (uStar)	Internal – Major	1	Electronics	Rectangular	23.5	23.5	80	40	14
16	Torque Coils	External – Major	2	Electronics	Rectangular	22.4	44.8	75	75	4
17	Aspect Camera	External – Major	1	Optics/Electronics	Rectangular	10.7	10.7	32	32	28
18	Camera Holder	External – Minor	1	Dalrin	Rectangular	3	3	45	34	15
19	Antenna	External – Major	1	Spring Steel/Dalrin	Rectangular	21.3	21.3	10	340	6
20	Aluminum Bottom Plate	External – Minor	1	Aluminum	Plate	32.7	32.7	110	110	1
21	Flight Wire	Internal – Minor	12	Insulated Wire 20 c	wire	0.6	7.2	1	20	1

Total Mass
1201.7 kg

Guide/Descriptions of Each Column

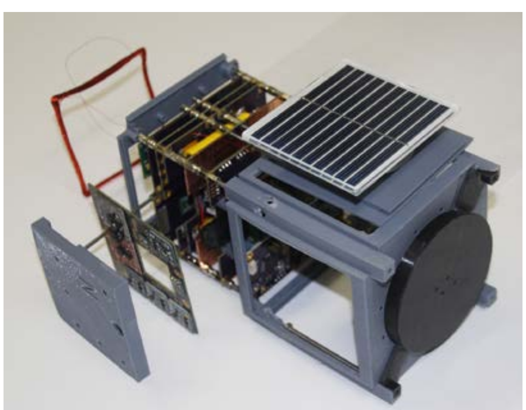
Row Number: List Components in decreasing importance (Follow Column C)
Name: List your CubeSat first as the parent, and each component and subsystem associated with your CubeSat
External /Internal: Rank CubeSat components from External to Internal and Major to Minor
Qty: List the quantity of component
Material: List the parent material for the component, specify alloy type if possible
Body Type: List the general shape of the component
Unit Mass List the mass a single component in grams
Total Mass List the mass for the total quantify of this component in the satellite (Qty * Unit Mass) = Total mass
Dimensions: List the Width/Length/Height in millimeters
Total System I the sum of all the total mass should equal the cubesat's full listed mass in all documents.

Outer Dimensions of 1U structure (meets all mechanical requirements for launcher)

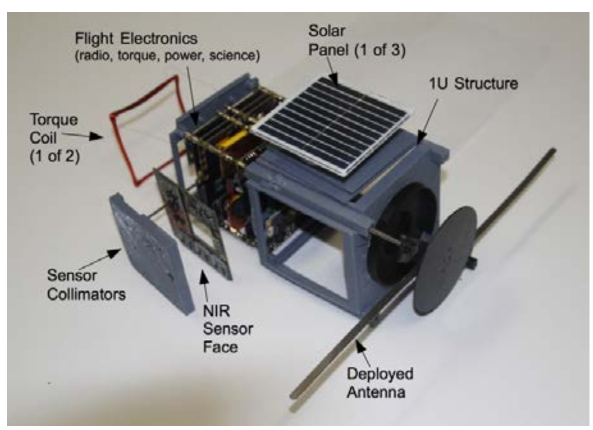


Images of the final flight system (deployed and stowed antenna)

EdgeCube: Antenna Stowed in Black Dalrin canister on right (79 mm diameter)



EdgeCube: Antenna Deployed (17 cm antenna tip to tip; popped up 3.5 cm from stowed location: cover disk 79 mm diameter)



CubeSat Developer: Sonoma State University

CubeSat Name: EdgeCube

Date Provided: May 12, 2018

Purpose: The purpose of this document is to provide a listing of materials that have been selected for use in the CubeSats.
http://outgassing.nasa.gov/

Table 1 – Metals

Item #	Material ID	Specification	Description	% TML	% CVCM	Location	Data Reference
1	Stainless Steel	Retains straight form after releasd (determined by testing)	Two Antenna blades	N/D	N/D	Top face of 1U structure; pops up 4 cm	N/D
2	Aluminum	3D printed by Moog	1U structure	N/D	N/D	Main 1U body and top and bottom faces	N/D
4	Steel	For mechanical structure	Threaded rods spacers, nuts 4-40 size	N/D	N/D	1U electronics support structure	N/D
5	Copper	Solderable	Lugs soldered to copper wire with low outgassing coatings	N/D	N/D	Solar panel connections	N/D

Table 2 – Non-Metal

Item #	Material ID	Specification	Description	% TML	% CVCM	Location	Data Reference
1	Dalrin	machinable	Antenna support	N/D	N/D	Top of 1U as part of antenna	N.D
2	Dalrin	machinable	Sensor Collimators	N/D	N/D	One side face of 1U box	N/D
3	Glass	UV resistant	Covers for Solar panels	N/D	N/D	Three side faces of 1U box	N/D

4	PC boards	Conformally coated	With electronic components	N/D	N/D	Most of the interior of he 1U box	N/D
5	SMA coax cable		Antenna connector	N/D	N/D	From RF electronic board to the center fed dipole antenna	N/D

Table 3 – Surface Coatings

Item #	Material ID	Specification	Description	% TML	% CVCM	Location	Data Reference
1	Adonization	Black	Coating for launch rails	0.67	0.05	Rail surfaces that contact the dispenser rails	N/D
2	PC board coatings	Protective insulating layer	Solder mask for PC boards	N/D	N/D	All flight boards that fill the interior space of the 1U box	N/D

Table 4 – Elastomerics

Item #	Material ID	Specification	Description	% TML	% CVCM	Location	Data Reference
None	None	N/A	N/A	N/A	N/A	N/A	N/A

Table 5 – Adhesives

Item #	Materia l ID	Specification	Description	% TM L	% CVC M	Location	Data Reference
1	Kapton Tape	Acrylic Adhesive	Tape	0.62	0.12	Solar Panel Harness	GSFC3590
2	epoxy	3M Scotch-Weld 2216 Epoxy Adhesive	Low outgassing epoxy	N/D	N/D	Stake down for solar panel leads; 4-40 nuts for frame	Flight tested by CalPoly CubeSat team

Table 6 – Miscellaneous

Item #	Material ID	Specification	Description	% TM L	% CVC M	Location	Data Reference
1	Solder	nominal	N/D	N/D	N/D	Electronic boards	N/D

Notes:

N/A Non Applicable

N/D No Data Available