ELVL-2016-0044466 (Comm License)
July 27, 2016

Orbital Debris Assessment for
The CubeSats on the
CRS (OA7) /ElaNa-17 Mission

per NASA-STD 8719.14A
(Communications License Review)

Signature Page

Justin Treptow, Analyst, NASA KSC VA-H1

Scott Higginbotham, Mission Manager, NASA KSC VA-C

National Aeronautics and
Space Administration

John F. Kennedy Space Center, Florida
Kennedy Space Center, FL 32899

ELVL-2016-0044466

Reply to Attn of: VA-H1

July 27, 2016

TO: Scott Higginbotham, LSP Mission Manager, NASA/KSC/VA-C

FROM: Justin Treptow, NASA/KSC/VA-H1

SUBJECT: Orbital Debris Assessment Report (ODAR) for the ElaNa-17 Mission (Communication License Review)

REFERENCES:

A. *NASA Procedural Requirements for Limiting Orbital Debris Generation*, NPR 8715.6A, 5 February 2008
B. *Process for Limiting Orbital Debris*, NASA-STD-8719.14A, 25 May 2012
C. Renaud, Patric "RE: Update to 1602RTRJ topo01- Reference Trajectory version 1" 8 July 2015. E-mail.
D. McKissock, Barbara, Patricia Loyselle, and Elisa Vogel. *Guidelines on Lithium-ion Battery Use in Space Applications*. Tech. no. RP-08-75. NASA Glenn Research Center Cleveland, Ohio
E. *UL Standard for Safety for Lithium Batteries, UL 1642*. UL Standard. 4th ed. Northbrook, IL, Underwriters Laboratories, 2007
F. Kwas, Robert. Thermal Analysis of ELaNa-4 CubeSat Batteries, ELVL-2012-0043254; Nov 2012
G. Range Safety User Requirements Manual Volume 3- Launch Vehicles, Payloads, and Ground Support Systems Requirements, AFSCM 91-710 V3.
H. HQ OSMA Policy Memo/Email to 8719.14: CubeSat Battery Non-Passivation, Suzanne Aleman to Justin Treptow, 10, March 2014

The intent of this report is to satisfy the orbital debris requirements listed in ref. (a) for the ElaNa-17 auxiliary mission launching in conjunction with the OA7 primary payload. It serves as the final submittal in support of the spacecraft Safety and Mission Success Review (SMSR). Sections 1 through 8 of ref. (b) are addressed in this document; sections 9 through 14 fall under the requirements levied on the Department of Defense's Operationally Responsive Space Office and are not presented here.

The following table summarizes the compliance status of the ElaNa-17 auxiliary payload mission flown on CRS/OA7. The five CubeSats comprising the ElaNa-17 mission are fully compliant with all applicable requirements.

Table 1: Orbital Debris Requirement Compliance Matrix

Requirement	Compliance Assessment	Comments
4.3-1a	Not applicable	No planned debris release
4.3-1b	Not applicable	No planned debris release
4.3-2	Not applicable	No planned debris release
4.4-1	Compliant	On board energy source (batteries) incapable of debris-producing failure
4.4-2	Compliant	On board energy source (batteries) incapable of debris-producing failure
4.4-3	Not applicable	No planned breakups
4.4-4	Not applicable	No planned breakups
4.5-1	Compliant	
4.5-2	Not applicable	
4.6-1(a)	Compliant	Worst case lifetime 2.3 yrs
4.6-1(b)	Not applicable	
4.6-1(c)	Not applicable	
4.6-2	Not applicable	
4.6-3	Not applicable	
4.6-4	Not applicable	Passive disposal
4.6-5	Compliant	
4.7-1	Compliant	Non-credible risk of human casualty
4.8-1	Compliant	No planned tether release under ElaNa-17 mission

Section 1: Program Management and Mission Overview

The ElaNa-17 mission is sponsored by the Space Operations Mission Directorate at NASA Headquarters. The Program Executive is Jason Crusan. Responsible program/project manager and senior scientific and management personnel are as follows:

CSUNSat1: Dr. Sharlene Katz, Principle Investigator / Project Manager
CXBN-2: Dr. Benjamin K. Malphrus, Principle Investigator / Project Manager
HARP: Dr. J. Vanderlei Martins, Principle Investigator / Project Manager
IceCube: Dr. Dong L. Wu, Principle Investigator; Dr. Jeffery R. Piepmeier, Project Manager
OpenOrbiter1: Dr. Ronald Marsh, Principle Investigator; Jeremy Straub, Project Manager

Program Milestone Schedule

Task	Date
CubeSat Selection	April 20, 2015
CubeSat Delivery to NanoRacks	November 14, 2016
Dispenser Delivery to NASA for Stowage	November 30, 2016
Launch	December 30, 2016

Figure 1: Program Milestone Schedule

The ElaNa-17 mission will be launched as an auxiliary payload on the OA-7 CRS mission on an Antares 230 launch vehicle from Wallops Flight Facility, VA. The ElaNa-17, will deploy 5 pico-satellites (or CubeSats). The CubeSat slotted position is identified in Table 2: ELaNa-17 CubeSats. The ElaNa-17 manifest includes: CSUNSat1, CXBN-2, HARP, IceCube, OpenOrbiter1. The current launch date is in December 30, 2016. The 5 CubeSats are to be ejected from a NanoRack's ISS deployer Q1 of 2017, placing the CubeSats in an orbit approximately 400 X 400 km at inclination of 51.6 deg (ref. (c)).

Each CubeSat ranges in sizes from a 10 cm cube to 10 cm x 10cm x 30 cm, with masses from about 1 kg to 5 kg total. The CubeSats have been designed and universities and government agencies and each have their own mission goals.

Section 2: Spacecraft Description

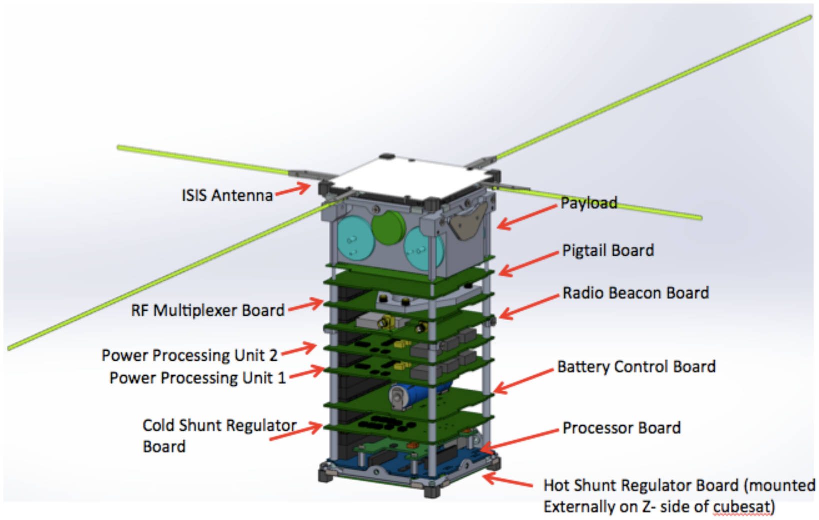
There are five CubeSats flying on the ElaNa-17 Mission. They will be deployed out of the NanoRacks ISS deployer in Q1 of 2017, as shown in Table 2: ELaNa-17 CubeSats below.

Table 2: ELaNa-17 CubeSats

CubeSat Quantity	CubeSat size	CubeSat Names	CubeSat Masses (kg)
1	2U (10 cm X 10 cm X 22.7 cm)	CSUNSat1	2.16
1	2U (11.3 cm X 11.3 cm X 22.7 cm)	CXBN-2	2.818
1	3U (10 cm X 10 cm X 36.8 cm)	HARP	4.766
1	2U (10 cm X 10 cm X 20 cm)	IceCube	4.5
1	1U (10 cm X 10 cm X 11.3 cm)	OpenOrbiter1	0.979

The following subsections contain descriptions of these five CubeSats.

CSUNSat1 – California State University Northridge (CSUN) / Jet Propulsion Laboratory(JPL) – 2U



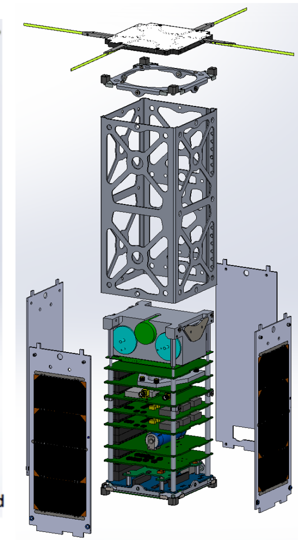


Figure 2: CSUNSat1 Xray View (Left) Figure 3: CSUNSat1 Exploded View (Right)

CSUNSat1 is a 2U CubeSat jointly developed by California State University Northridge (CSUN) and the Jet Propulsion Laboratory (JPL). The objective of the CSUNSat1 mission is to space test a new low-temperature capable, Li-ion battery/supercapacitor hybrid power system. This innovation would reduce the mass and volume of power systems and eliminate the need for wasteful battery heaters and thereby increase the amount of energy and power available at for low-temperatures science and engineering operations encountered in deep space missions.

30 minutes after release from the deployer, *CSUNSat1* will power up and execute an initialization process that includes charging the spacecraft battery and deploying the antenna. After initialization the follow mission phases will be executed.

- Spacecraft Checkout: A set of tests to verify spacecraft performance and charge the spacecraft battery
- Payload Checkout: A single charge/discharge cycle of the payload battery
- Primary Experiments: A series of ground station controlled designed to characterize the battery, supercapacitors, and hybrid system at several temperatures
- Extended Mission: Based on the successful performance of the primary experiments, the satellite will switch from the spacecraft to the payload battery as the primary source of stored energy for the remainder of the mission.

The primary CSUNSat1 structure is made of 5052-H32 Aluminum. The radio and beacon use an ISIS Deployable Antenna System (Double UHF Dipole) made from Aluminum 6082, Polycarbonate, and Nitinol. The solar panel substrates are made of Aluminum 6061 with XTJ cells mounted on them. The remaining components contain all standard commercial off the shelf (COTS) materials, electrical components, and PCBs. CSUNSat1 has no propulsion and no attitude control.

There are no pressure vessels, hazardous or exotic materials.

The spacecraft's electrical power storage system consists of Panasonic NCR18650 Lithium batteries. The payload experiment battery is an A123 Systems/Navitas 26650 Li-ion Cell (Manufacturer Serial # TXN10293).

Cosmic X-Ray Background Nanosatellite -2 (CXBN-2)
Morehead State University 2U

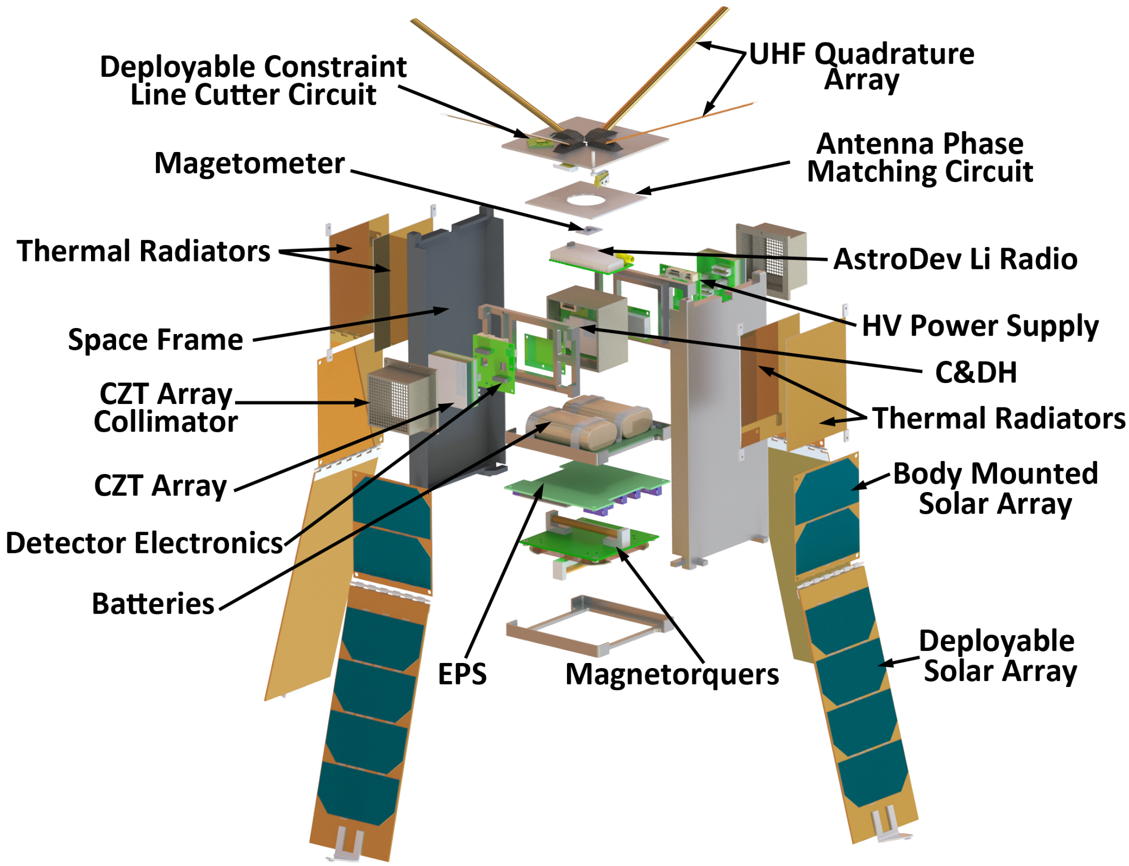


Figure 4: CXBN-2 Expanded View

CXBN-2 is a follow-on mission to CXBN, a 2-U CubeSat that was launched on September 13, 2012 as a secondary payload on the NASA ELaNa VI OUTSat mission. While CXBN is successfully operated on orbit, a number of improvements are envisioned that would improve the precision of the scientific measurement (increase the S/N) made by CXBN and improve the reliability of the spacecraft bus while advancing the flight software and therefore the mission and spacecraft capabilities. CXBN-2 is being developed with these design improvements incorporated. Mission operations at Morehead State University (MSU) now utilizes the substantial gain of the MSU 21 m Antenna system, when combined with Software Defined Radio systems and techniques, significantly reduces mission risk by implementing the ability to detect and decode extremely weak beacons, telemetry, and down-linked data from small spacecraft in LEO with limited prime power and transmission power.

The goal of the CXBN-2 mission is to increase the precision of measurements of the Cosmic X-Ray Background in the 30-50 keV range top a precision of <5%, thereby constraining models that attempt to explain the relative contribution of proposed sources lending insight into the underlying physics of the early universe. The mission addresses a fundamental science question that is clearly central to our understanding of the structure, origin, and evolution of the universe by potentially lending insight into both the high energy background radiation and into the evolution of primordial galaxies. CXBN-2 will map the Extragalactic Diffuse X-Ray Background (DXB) with a new breed of Cadmium Zinc Telluride (CZT) detector (first flown on CXBN) but with twice the detector array area of its precursor and with careful characterization and calibration. The DXB is a powerful tool for understanding the early universe and provides a window to the most energetic objects in the far-away universe. Although studied previously, existing measurements disagree by about 20%. With the novel CZT detector aboard CXBN-2 and an improved array configuration, a new, high precision measurement is possible. In ~1 year of operation the experiment will have collected 3 million seconds of good data, reaching a broadband S/N ~250.

Upon deployment from the NanoRacks CubeSat Dispenser (NRCSD), CXBN-2 will power up its systems and start count down timers. At Deployment T+30 minutes, the solar arrays, antennas, and thermal radiators will be deployed, then at 45 minutes the UHF beacon will be activated. For the first several passes the ground station operators at Morehead State University will attempt communications to perform checkouts of the spacecraft. Approximately 6 days from launch, payload tests will begin and continue for at least 1 year.

The CubeSat structure is made of Aluminum 6061-T6. It contains standard commercial off the shelf (COTS) materials, electrical components, custom PCBs and solar cells. The UHF radio uses a quadrature array of blade antennas

There are no pressure vessels, hazardous, radioactive or exotic materials. The X-Ray detector collimator is composed of a 3-D printed Tungsten composite material printed with a polymeric binder that has been analyzed by LSP.

The electrical power storage system consists of common lithium-ion batteries (Boston Power Swing 5300) with over-charge/current protection circuitry and venting capabilities. The lithium batteries carry the following certifications: UN 38.3, UL1642, IEC 62133, ROHS 2002/95/EC, CTIA IEEE 1725 and testing for spaceflight readiness was conducted at NASA JSC.

HARP – UMBC (University of Maryland, Baltimore County) – 3U

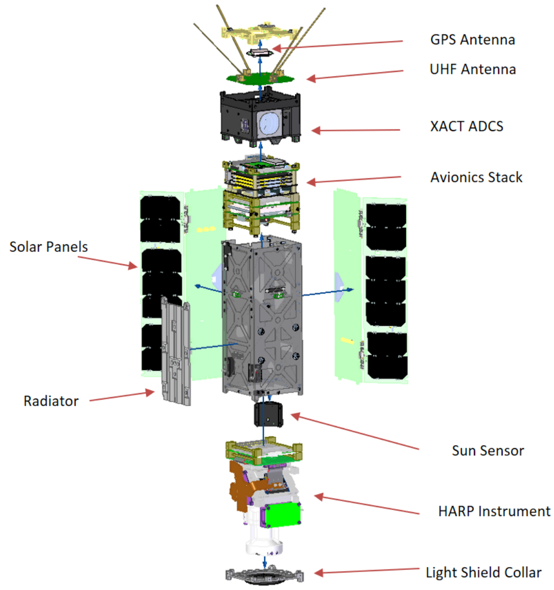


Figure 5: HARP Expanded View

The HyperAngular Rainbow Polarimeter (HARP) mission is designed to measure the microphysical properties of atmospheric aerosols, cloud water and ice particles. HARP is a precursor for the new generation of imaging polarimeters to be used for the detailed measurements of aerosol and cloud properties in larger missions. The HARP payload is a wide field-of-view (FOV) imager that splits three spatially identical images into three independent polarizers and detector arrays. This technique achieves simultaneous imagery of three polarization states and is the key innovation to achieve high polarimetric accuracy with no moving parts. The spacecraft consists of a 3U CubeSat with 3-axis stabilization designed to keep the imager pointing nadir during the data acquisition period.

Upon deployment from the ISS NanoRacks Deployer, HARP will power up and start counting down timers. At 30 minutes, the antennas and solar array will be deployed, then at 45 minutes the UHF Radio will be activated and able to transmit but still only upon command from the ground. For the first few passes the ground station operators will attempt communications to perform checkouts of the spacecraft. Approximately 4 days from launch, payload tests will begin and continue for 4-12 months until the spacecraft burns up in the atmosphere.

The CubeSat structure is made of Aluminum 7075. It contains all standard commercial off the shelf (COTS) materials, electrical components, PCBs and solar cells.

There are no pressure vessels, hazardous or exotic materials.

The electrical power storage system consists of common lithium-ion batteries with over-charge/current protection circuitry. They are provided by ClydeSpace.

IceCube – NASA Goddard Space Flight Center – 3U

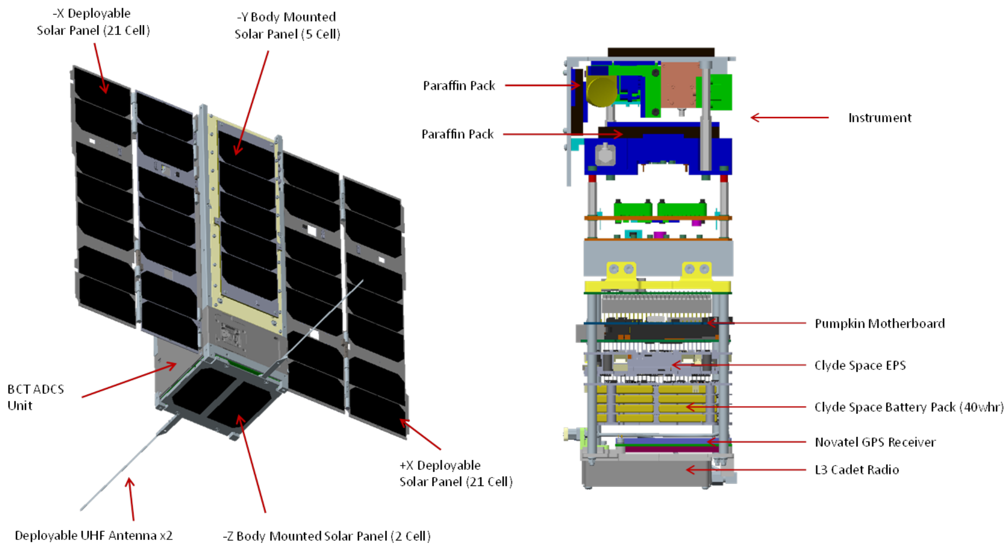


Figure 6: IceCube Deconstructed View

IceCube is an Earth Science technology validation mission with the objective of raising the technology readiness level (TRL) of 900-GHz sub-millimeter wave radiometer technology from 5 to 7. Sub-millimeter wave technology enables a new class of spaceflight radiometers sensitive to ice clouds. NASA's Goddard Space Flight Center (GSFC) and it's Wallops Flight Facility (WFF) has partnered with Virginia Diodes, Inc (VDI) to qualify commercially available 900-GHz receiver technology for spaceflight and demonstrate the radiometer performance aboard a 3-U CubeSat in a low Earth orbit environment. IceCube is funded by NASA's Earth Science Technology Office and NASA's Science Mission Directorate.

IceCube will be deployed from a NanoRacks Dispenser. Thirty minutes after release from the ISS, the vehicle will begin deploying solar panels (2 wings) and dipole UHF antenna. There are no detachable parts. The vehicle is solar-inertial pointed with solar panels normal to the sun-line, and spins at a nominal rate of 3 minutes per revolution about the sun-line. Power management will be such as to preserve positive margin throughout the orbit, with the science instrument typically switched off during night time. Operations lifetime is expected to be 70 days or less. No spacecraft control is planned after this time, though re-entry.

The mechanical structure is made of Al 6061-T651. There are 4 threaded 304 Stainless Steel rods with total mass of 52 grams. All fasteners are either A286 alloy or 300 series stainless steel. Exterior thermal tape is Silicon Oxide/Aluminized Kapton. Printed circuit boards are FR4, with Sn62 or Sn63 (Tin/Lead) solder. Locking inserts are Nitronic 60. There are no materials identified that could survive entry.

There are no hazardous systems on the satellite.

The 40Wh battery pack is commercially made by Clyde Space, model number CS-SBAT2-40. These batteries contain 8 VARTA lithium polymer 16-02324 cells.

OpenOrbiter 1 – University of North Dakota – 1U

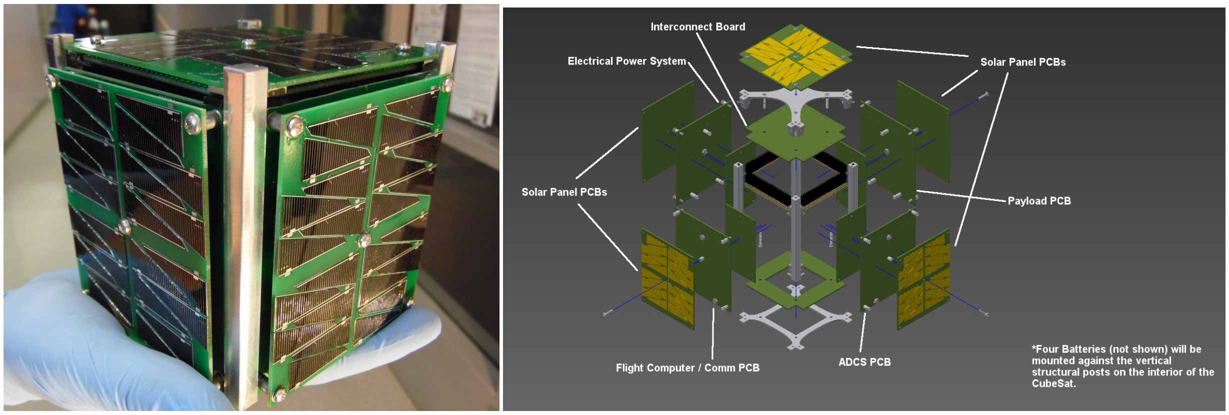


Figure 7: OpenOrbiter-1 Expanded View

OpenOrbiter-1 will demonstrate the effectiveness of ultra-low cost COTS (consumer off the shelf) parts from an open-source design and capture the on-orbit characteristics of the designs. Validation of the designs in the primary mission with a secondary mission of earth imagining and testing image-mosaicking algorithms

Following deployment from the NanoRacks CubeSat Dispenser (NRCSD), solar cells, battery charge, and the 30 minute system hold timer will activate. Upon completion of the 30 minute hold, primary voltage conversion will begin, powering the system. The next several orbits will be used to validate full system startup and characterize on-orbit performance of the satellite through telemetry downlink. Image mosaicking and data processing will also be conducted during this time. Mission life is expected to be 3-6 months.

The structure of the CubeSat will be made out of 6061 Aluminum. The primary radio antenna will be made out of Mylar coated steel. COTS parts will be used for the remaining materials, electrical components, solar cells, and PCBs.

No hazardous systems are present on the satellite.

Batteries are typical COTS lithium-ion batteries that has IC protection against shorts, over-discharge, and over-charge situations. The lithium cells have an UL number of MH12210.

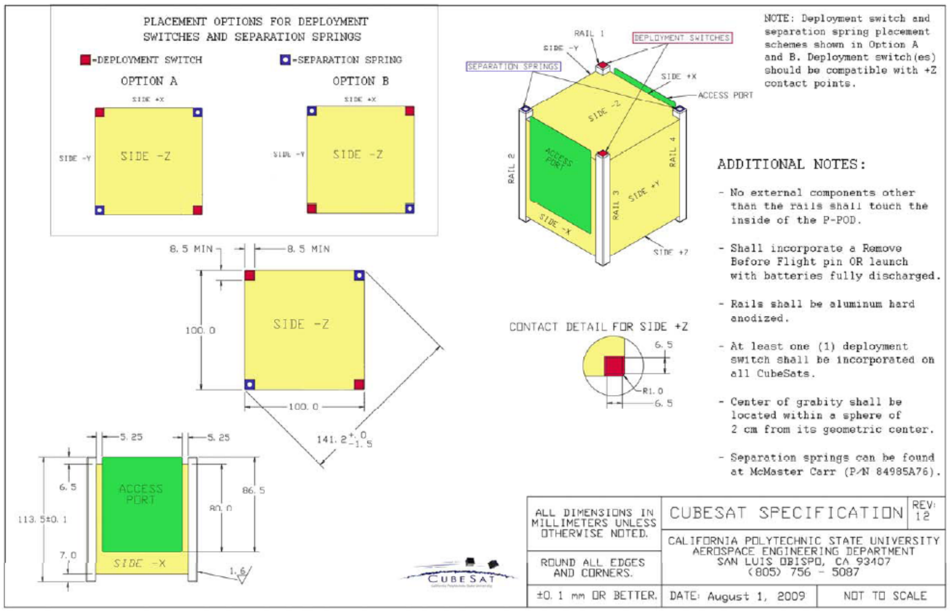


Figure 8: 1U CubeSat Specification

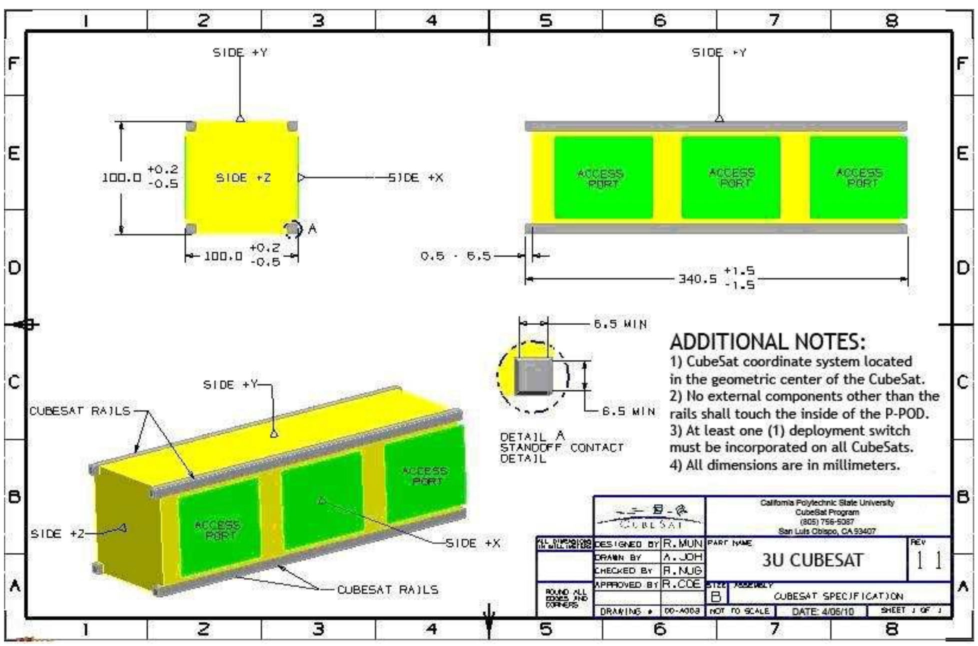


Figure 9: 3U CubeSat Specification

Section 3: Assessment of Spacecraft Debris Released during Normal Operations

The assessment of spacecraft debris requires the identification of any object (>1 mm) expected to be released from the spacecraft any time after launch, including object dimensions, mass, and material.

The section 3 requires rationale/necessity for release of each object, time of release of each object, relative to launch time, release velocity of each object with respect to spacecraft, expected orbital parameters (apogee, perigee, and inclination) of each object after release, calculated orbital lifetime of each object, including time spent in Low Earth Orbit (LEO), and an assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2.

No releases are planned on the ElaNa-17 CubeSat mission therefore this section is not applicable.

Section 4: Assessment of Spacecraft Intentional Breakups and Potential for Explosions.

There are NO plans for designed spacecraft breakups, explosions, or intentional collisions on the ElaNa-17 mission.

The probability of battery explosion is very low, and, due to the very small mass of the satellites and their short orbital lifetimes the effect of an explosion on the far-term LEO environment is negligible (ref (h)).

The CubeSats batteries still meet Req. 56450 (4.4-2) by virtue of the HQ OSMA policy regarding CubeSat battery disconnect stating;

> "CubeSats as a satellite class need not disconnect their batteries if flown in LEO with orbital lifetimes less than 25 years." (ref. (h))

Assessment of spacecraft compliance with Requirements 4.4-1 through 4.4-4 shows that with a lifetime of 1.3 years maximum the ElaNa-17 CubeSat is compliant.

Section 5: Assessment of Spacecraft Potential for On-Orbit Collisions

Calculation of spacecraft probability of collision with space objects larger than 10 cm in diameter during the orbital lifetime of the spacecraft takes into account both the mean cross sectional area and orbital lifetime.

The largest mean cross sectional area (CSA) among the five CubeSats is that of the IceCube CubeSat with solar panels deployed maintaining a solar internal attitude:

$$\boldsymbol{Mean\ CSA} = \frac{\sum \boldsymbol{Surface\ Area}}{\boldsymbol{4}} = \frac{[\boldsymbol{2} * (\boldsymbol{w} * \boldsymbol{l}) + \boldsymbol{4} * (\boldsymbol{w} * \boldsymbol{h})]}{\boldsymbol{4}}$$

Equation 1: Mean Cross Sectional Area for Convex Objects

$$\boldsymbol{Mean\ CSA} = \frac{(\boldsymbol{A_{max}} + \boldsymbol{A_1} + \boldsymbol{A_1})}{\boldsymbol{2}}$$

Equation 2: Mean Cross Sectional Area for Complex Objects

All CubeSats evaluated for this ODAR are stowed in a convex configuration, indicating there are no elements of the CubeSats obscuring another element of the same CubeSats from view. Thus, mean CSA for all stowed CubeSats was calculated using Equation 1. This configuration renders the longest orbital life times for all CubeSats.

Once a CubeSat has been ejected from the NanoRacks CubeSat Dispenser (NRCSD) and deployables have been extended Equation 2 is utilized to determine the mean CSA. A_{max} is identified as the view that yields the maximum cross-sectional area. A_1 and A_2 are the two cross-sectional areas orthogonal to A_{max}. Refer to Appendix A for dimensions used in these calculations

The IceCube orbit at deployment is 400 km apogee altitude by 400 km perigee altitude, with an inclination of 51.6 degrees. With an area to mass (4.5 kg) ratio of 0.035 m^2/kg, DAS yields 2.3 years for orbit lifetime for its stowed state, which in turn is used to obtain the collision probability. Table 4 below provides complete results.

There will be no post-mission disposal operation. As such the identification of all systems and components required to accomplish post-mission disposal operation, including passivation and maneuvering, is not applicable.

Table 3: CubeSat Orbital Lifetime & Collision Probability

	CubeSat	CSUNSat-1	CXBN-2	HARP*	IceCube	OpenOrbiter1
	Mass (kg)	2.16	2.818	4.766	4.5	0.979
Stowed	Mean C/S Area (m^2)	0.0277	0.032	0.042	0.035	0.0163
Stowed	Area-to Mass (m^2/kg)	0.0128	0.011	0.009	0.008	0.017
Stowed	Orbital Lifetime (yrs)	1.2	1.5	2	2.3	0.8
Stowed	Probability of collision (10^X)	0.00000	0.00000	0.00000	0.00000	0.00000
Deployed	Mean C/S Area (m^2)	0.0289	0.050	0.056	0.1602	0.0173
Deployed	Area-to Mass (m^2/kg)	0.0134	0.018	0.012	0.036	0.018
Deployed	Orbital Lifetime (yrs)	1.1	0.8	1.3	0.4	0.8
Deployed	Probability of collision (10^X)	0.00000	0.00000	0.00000	0.00000	0.00000

Solar Flux Table Dated 1/26/2016

* HARP operational attitude is nadir pointing, Mean C/S Area consists of average of solar panels perpendicular and parallel to velocity vector.

The probability of any ElaNa-17 spacecraft collision with debris and meteoroids greater than 10 cm in diameter and capable of preventing post-mission disposal is calculated to be less than 0.00000 by DAS, for any configuration. This satisfies the 0.001 maximum probability requirement 4.5-1.

Since the CubeSats have no capability or plan for end-of-mission disposal, requirement 4.5-2 is not applicable.

Assessment of spacecraft compliance with Requirements 4.5-1 shows ElaNa-17 to be compliant. Requirement 4.5-2 is not applicable to this mission.

Section 6: Assessment of Spacecraft Postmission Disposal Plans and Procedures

All ElaNa-17 spacecraft will naturally decay from orbit within 25 years after end of the mission, satisfying requirement 4.6-1a detailing the spacecraft disposal option.

Planning for spacecraft maneuvers to accomplish postmission disposal is not applicable. Disposal is achieved via passive atmospheric reentry.

Calculating the area-to-mass ratio for the worst-case (smallest Area-to-Mass) post-mission disposal among the CubeSats finds IceCube in its stowed configuration as the worst case. The area-to-mass is calculated for is as follows:

$$\frac{\boldsymbol{Mean\ {}^{C}/_{S}\ Area\ (m^2)}}{\boldsymbol{Mass\ (kg)}} = \boldsymbol{Area - to - Mass\ (\frac{m^2}{kg})}$$

Equation 3: Area to Mass

$$\frac{0.035\ m^2}{4.5\ kg} = \ 0.008\frac{m^2}{kg}$$

IceCube has the smallest Area-to-Mass ratio and as a result will have the longest orbital lifetime. The assessment of the spacecraft illustrates they are compliant with Requirements 4.6-1 through 4.6-5.

<u>DAS 2.0.2 Orbital Lifetime Calculations:</u>

DAS inputs are: 400 km maximum perigee 400 km maximum apogee altitudes with an inclination of 51.6 degrees at deployment in the year 2017. An area to mass ratio of 0.008 m^2/kg was imputed and DAS 2.0.2 yields a 2.3 years orbit lifetime for IceCube in its stowed state.

This meets requirement 4.6-1. For the complete list of CubeSat orbital lifetimes reference **Table 3: CubeSat Orbital Lifetime & Collision Probability**.

Assessment results show compliance.

Section 7: Assessment of Spacecraft Reentry Hazards

A detailed assessment of the components to be flown on ElaNa-17 was performed. The assessment used DAS 2.0, a conservative tool used by the NASA Orbital Debris Office to verify Requirement 4.7-1. The analysis is intended to provide a bounding analysis for characterizing the survivability of a CubeSat's component during re-entry. For example, when DAS shows a component surviving reentry it is not taking into account the material ablating away or charring due to oxidative heating. Both physical effects are experienced upon reentry and will decrease the mass and size of the real-life components as the reenter the atmosphere, reducing the risk they pose still further.

The following steps are used to identify and evaluate a components potential reentry risk relative to the 4.7-1 requirement of having less than 15 J of kinetic energy and a 1:10,000 probability of a human casualty in the event the survive reentry.

1. Low melting temperature (less than 1000 °C) components are identified as materials that would never survive reentry and pose no risk to human casualty. This is confirmed through DAS analysis that showed materials with melting temperatures equal to or below that of copper (1080 °C) will always demise upon reentry for any size component up to the dimensions of a 1U CubeSat.

2. The remaining high temperature materials are shown to pose negligible risk to human casualty through a bounding DAS analysis of the highest temperature components, stainless steel (1500°C). If a component is of similar dimensions and has a melting temperature between 1000 °C and 1500°C, it can be expected to posses the same negligible risk as stainless steel components. See Table 4.

Table 4: ELaNa-17 Stainless Steel DAS Analysis

CubeSat	High Temp Component	Material	Mass(g)	Demise Alt (km)	KE (J)
CSUNSat1	Delployable Antenna	NiTi Alloy	10	**0**	**1**
CSUNSat1	Battery	LiFePO4/ Stainless Steel	75	**67.6**	**0**
CXBN-2	Antennas and Mounts	Steel 410	19	**0**	**1**
CXBN-2	Fasteners	Stainless Steel (M2, M3, M4)	60	**76.5**	**0**
HARP	Solar Panel Hinges	Aluminum/ Stainless Steel	7	**0**	**2**
HARP	Separation Switch	Steel	2	**0**	**0**
HARP	Prism	Glass	74	**74**	**0**
HARP	Lens assembly (W/O front lens glass only)	Glass	80	**74.4**	**0**
HARP	prism holder	Titanium	8	**0**	**1**
HARP	Average Fasteners	Stainless Steel	82	**67.4**	**0**
IceCube	Fasteners	300/316 SS	133	**67.2**	**0**
OpenOrbiter 1	Antenna	COTS Steel	0	**0**	**3**
OpenOrbiter 1	Batteries	Steel 304, LiNiCoAlO2	200	**62.8**	**0**

The majority of stainless steel components demise upon reentry. The components that DAS conservatively identifies as reaching the ground have 3 or less joules of kinetic energy, far below the requirement of 15 joules. No stainless steel component will pose a risk to human casualty as defined by the Range Commander's Council. In fact, any injury incurred or inflicted by an object with such low energy would be negligible and wouldn't require the individual to seek medical attention.

Through the method described above, Table 4: ELaNa-17 Stainless Steel DAS Analysis, and the full component lists in the Appendix all CubeSats launching under the ElaNa-17 mission are conservatively shown to be in compliance with Requirement 4.7-1 of NASA-STD-8719.14A.

See the Appendix for a complete accounting of the survivability of all CubeSat components.

Section 8: Assessment for Tether Missions

ElaNa-17 CubeSats will not be deploying any tethers.

ElaNa-17 CubeSats satisfy Section 8's requirement 4.8-1.

Section 9-14

ODAR sections 9 through 14 for the launch vehicle are addressed in ref. (g), and are not covered here.

If you have any questions, please contact the undersigned at 321-867-2958.

/original signed by/

Justin Treptow
Flight Design Analyst
NASA/KSC/VA-H1

cc: VA-H/Mr. Carney
VA-H1/Mr. Beaver
VA-H1/Mr. Haddox
VA-C/Mr. Higginbotham
VA-G2/Mr. Marin
SA-D2/Mr. Hale
SA-D2/Mr. Hidalgo
Analex-3/Mr. Hibshman
Analex-22/Ms. Nighswonger

Appendix Index:

Appendix A. ElaNa-17 Component List by CubeSat: CSUNSat1

CUBESAT	Name	Qty	Material	Mass (g) (total)	Diameter/ Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp (C)	Comments
CSUNSat1	CSUNSat1(Entire Assembly)	-	-	Assembly	100	100	227	No	-	-
CSUNSat1	CubeSat Structure	1	Aluminum 5052-H32, Stainless Steel	254	100	100	227	No	Low Melting Temp	Demise
CSUNSat1	ISIS UHF Antenna (undeployed)	1	Aluminum 6061	100	98	98	7	No	Low Melting Temp	Demise
CSUNSat1	ISIS Delployable Antenna Elements	4	NiTi Alloy	10	1.5	120	5	Yes	1981	See Table 5
CSUNSat1	Solar Panels	4	Aluminum 6061	100	1.6	82	224	No	Low Melting Temp	Demise
CSUNSat1	Hot Shunt Regulator Board	1	FR4/ Sn solder/Cu	37	96	92	5	No	Low Melting Temp	Demise
CSUNSat1	Processor Board	1	FR4/ Sn solder/Cu	93	96	92	5	No	Low Melting Temp	Demise
CSUNSat1	Cold Shunt Regulator Board	1	FR4/ Sn solder/Cu	49	96	92	5	No	Low Melting Temp	Demise
CSUNSat1	Battery Control Board	1	FR4/ Sn solder/Cu	104	96	92	5	No	Low Melting Temp	Demise
CSUNSat1	Panasonic NCR18650B Battery	1	Li-ion	46	19		65	No	Low Melting Temp	Demise
CSUNSat1	Power Processing Unit 1	1	FR4/ Sn solder/Cu	77	96	92	5	No	Low Melting Temp	Demise
CSUNSat1	Power Processing Unit 2	1	FR4/ Sn solder/Cu	49	96	92	5	No	Low Melting Temp	Demise
CSUNSat1	Radio Beacon Board	1	FR4/ Sn solder/Cu	79	96	92	5	No	Low Melting Temp	Demise
CSUNSat1	RF Multiplexer Board	1	FR4/ Sn solder/Cu	106	96	92	5	No	Low Melting Temp	Demise
CSUNSat1	Pigtail Board	1	FR4/ Sn solder/Cu	50	96	92	5	No	Low Melting Temp	Demise
CSUNSat1	Payload Board	1	FR4/ Sn solder/Cu	50	96	92	5	No	Low Melting Temp	Demise

CUBESAT	Name	Qty	Material	Mass (g) (total)	Diameter/ Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp (C)	Comments
CSUNSat1	Battery	1	LiFePO4/ Stainless steel	75	26	-	65	Yes	1400	See Table 5
CSUNSat1	Supercapacitors	2	Aluminum 1100	63	33	-	65	No	Low Melting Temp	Demise
CSUNSat1	Battery/Capacitor Clamp	1	Aluminum	315	10	10	5	No	Low Melting Temp	Demise
CSUNSat1	Standoffs, nuts, screws	mulitiple	Aluminum/ Copper	48	Various	Various	Various	No	Low Melting Temp	Demise

Appendix B. ElaNa-17 Component List by CubeSat: CXBN-2

CUBESAT	Name	Qty	Material	Mass (g) (total)	Diameter/ Width (mm)	Length (mm)	Height (mm)	Melting Temp	Comments
CXBN-2	CXBN-2	1	Aluminum 6061	-	-	-	-	Low Melting Temp	Demise
CXBN-2	2U Structure	1	Aluminum 6061	520	113	113	227	Low Melting Temp	Demise
CXBN-2	Antennas and Mounts	4	Steel 410	19	10	180	1	1500	See Table 5
CXBN-2	Solar Panels (4 cell)	4	FR-4 PCB (4 cells)	360	82	216.5	27	Low Melting Temp	Demise
CXBN-2	Solar Panels (2 cell)	4	FR-4 PCB (2 cells)	180	80	90	1.2	Low Melting Temp	Demise
CXBN-2	Thermal Radiator System	4	Gold, Copper, Stainless Steel, FR-4 PCB, Brass	144	75	95	3	Low Melting Temp	Demise
CXBN-2	Sep Switches	3	Steel, Brass, Thermoplastic Polyester	6	5.5-6	15	13-15	Low Melting Temp	Demise
CXBN-2	Batteries	2	Lithium Ion Batteries (Swing 5300)	186	37	64.8	19.1	Low Melting Temp	Demise
CXBN-2	ACS (Magenetorqure)	1	HyMu-80, EFI Alloy 50	300	95	95	45.1	Low Melting Temp	Demise
CXBN-2	ADS (IMU Integrated into C&DH, Sun Sensors)	1	FR-4 PCB, Resistor, Capacitor, IMU	11	14	18.7	2.3	Low Melting Temp	Demise
CXBN-2	Payload System (CZT Detector + Shielding)	2	CZT, Aluminum, Epoxy, Tungsten Powder, FR-4 PCB, ZE4 Connectors, Gold, Copper, TFM Connectors	620	54	54	40	Low Melting Temp	Demise
CXBN-2	Comms Board	1	Aluminum, FR-4 PCB, SMA Connector, black liquid crystal polymer Connector	90	32	62	12	Low Melting Temp	Demise
CXBN-2	Battery Board (EPS)	1	Aluminum, FR-4 PCB, Stainless Steel, Connectors, Epoxy	114	95	95	35	Low Melting Temp	Demise
CXBN-2	C&DH Board	1	FR-4 PCB, Stainless Steel, ZE4 and ZE8 Connectors, Connector	18	46	46	18	Low Melting Temp	Demise
CXBN-2	Fasteners	275	Stainless Steel (M2, M3, M4)	60.116	4	6.1	-	1500	See Table 5
CXBN-2	Cabling	TBD	Various (Teflon Wiring)	-	50		-	Low Melting Temp	Demise
CXBN-2	Epoxies, Tape, Adhesives		Various	160	160	Conformal	-	Low Melting Temp	Demise

Appendix C. ElaNa-17 Component List by CubeSat: HARP
Appendix D.

CUBESAT	Name	Qty	Material	Mass (g) (total)	Diameter/ Width (mm)	Length (mm)	Height (mm)	Melting Temp	Comments
HARP	Thermal Knife Deployer	2	G10/Aluminum	1	10.7	17.5	5.1	Low Melting Temp	Demise
HARP	Sun Sensor Assembly	1	Aluminum 6061-T6	25	35.6	35.6	40.9	Low Melting Temp	Demise
HARP	Detector cage	1	Aluminum	161	50	60	45	Low Melting Temp	Demise
HARP	Prism	3	Glass	74	45	25	35	1400	See Table 5
HARP	Lens assembly (W/O front lens glass only)	8	Glass	80	30	4		1400	See Table 5
HARP	Lens assembly aluminum structure	1	aluminum	167	75	70	1	Low Melting Temp	Demise
HARP	power board mount	1	aluminum	17	45	12	2.5	Low Melting Temp	Demise
HARP	TIM electronic board	1	PCB	115	90	90	10	Low Melting Temp	Demise
HARP	Camera power board	1	PCB	53	80	25	15	Low Melting Temp	Demise
HARP	Detector	3	Ceramic	32	36	24	2	Low Melting Temp	Demise
HARP	Detector electronics board	3	PCB	53	30	45	2	Low Melting Temp	Demise
HARP	BusBar	1	Copper	176	4	150	100	Low Melting Temp	Demise
HARP	Detector Strap	3	Copper	33	15	75	1	Low Melting Temp	Demise
HARP	SDL Standoffs	8	Aluminum	9	12.7	95.9	19	Low Melting Temp	Demise
HARP	ClydeSpace Standoffs	4		0.5	6.35		25.4	Low Melting Temp	Demise
HARP	Electronic Stack Mounts	4	Aluminum 6061-T6	2	11.5	16.5	9.5	Low Melting Temp	Demise
HARP	Shutter	1	Aluminum	28	75	3		Low Melting Temp	Demise
HARP	Prism holder	1	Titanium	8	45	35	3	1660	See Table 5
HARP	Prism mount	1	Aluminum	17	45	35	30	Low Melting Temp	Demise
HARP	Stack spacers	4	Aluminum	39	10	90	10	Low Melting Temp	Demise
HARP	Electrical harness	1	Copper-PTFE	30	1	50	1	Low Melting Temp	Demise
HARP	4-40 x 0.375" Detector Assembly	12	300 Series Stainless Steel	7.87	2	9	-	See Average Fastener Results	
HARP	2-56 x 0.125" Detector Assembly	12	18-8 Stainless Steel	3.15	1	3	-	See Average Fastener Results	
HARP	2-64 x 0.188" Detector Assembly	12	18-8 Stainless Steel	3.15	1.5	5	-	See Average Fastener Results	

CUBESAT	Name	Qty	Material	Mass (g) (total)	Diameter/ Width (mm)	Length (mm)	Height (mm)	Comments
HARP	Ø.062" x 0.188" Detector Assembly	12	18-8 Stainless Steel	0.89	19	5	-	See Average Fastener Results
HARP	Ø0.750" Snap Ring Lense Assembly 1	1	Stainless steel	0.66	1.5	1	-	See Average Fastener Results
HARP	6-40 x 0.375" Lense Assembly 2	4	18-8 Stainless Steel	4.72	5	9	-	See Average Fastener Results
HARP	6-40 x 0.5" Lense Assembly 2	4	18-8 Stainless Steel	5.24	5	13	-	See Average Fastener Results
HARP	1-72 x 0.125" Lens Assembly 2	6	18-8 Stainless Steel	0.79	1	3	-	See Average Fastener Results
HARP	1-72 x 0.188" Lense Assembly 2	4	18-8 Stainless Steel	0.52	1	22	-	See Average Fastener Results
HARP	2-56 x 0.25" Lense Assembly 1	3	18-8 Stainless Steel/ Black Oxide	0.79	1.5	6	-	See Average Fastener Results
HARP	Ø0.125" x .375" Lense Assembly 1	2	18-8 Stainless Steel	1.23	3	9	-	See Average Fastener Results
HARP	Ø0.125" x .5" Lense Assembly 2	2	18-8 Stainless Steel	1.63	3	13	-	See Average Fastener Results
HARP	4-40 x0.25" Detector Assembly	12	300 Series Stainless Steel	6.29	2	6	-	See Average Fastener Results
HARP	4-40 x0.188" Thermal Assembly	3	18-8 Stainless Steel	1.57	2	5	-	See Average Fastener Results
HARP	4-40 x0.313" Thermal Assembly	15	18-8 Stainless Steel	9.83	2	8	-	See Average Fastener Results
HARP	1-64 x 0.25" Prism Assembly	6	18-8 Stainless Steel	0.79	1	6	-	See Average Fastener Results
HARP	Ø0.062" x .25" Prism Assembly	2	18-8 Stainless Steel	0.20	1.5	6	-	See Average Fastener Results
HARP	#4 washer General	39	300 Series Stainless Steel	3.07	5	1	-	See Average Fastener Results
HARP	#6 washer General	8	18-8 Stainless Steel	1.05	6.5	1	-	See Average Fastener Results
HARP	2-56x0.188 Phillips Head Bolt	4	SS 316	0.95	1.5	5	-	See Average Fastener Results
HARP	2-56x0.188 Socket Head Bolt	2	SS 303	0.58	1.5	5	-	See Average Fastener Results
HARP	2-56x0.25 Socket Head Bolt	12	SS 303	4.08	1.5	5	-	See Average Fastener Results
HARP	093-187x0.1 Washer	12	SS 316	0.19	4	2	-	See Average Fastener Results
HARP	2-56x0.25 Phillips Head Bolt	34	SS 304	8.02	1.5	6	-	See Average Fastener Results
HARP	1-64x0.25 Socket Head Bolt	4	6061-T6	0.19	1.5	5	-	See Average Fastener Results
HARP	8-32x.049 Flat Washer	4	SS 304	3.16	10	1	-	See Average Fastener Results

CUBESAT	Name	Qty	Material	Mass (g) (total)	Diameter/ Width (mm)	Length (mm)	Height (mm)	Melting Temp	Comments
HARP	8-32x0.375 Socket Head Bolt	4	SS 303	8.40	8	10	-	See Average Fastener Results	
HARP	2-56x0.125 Shoulder Bolt	4	SS 316	1.13	1.5	3	-	See Average Fastener Results	
HARP	2-56x0.375 Phillips Head Bolt	2	SS 304	0.66	1.5	10	-	See Average Fastener Results	
HARP	2-56 Hex Nut	2	SS 304	0.46	3	1	-	See Average Fastener Results	
HARP	6-32x.4375 Flat Head Phillips Machine Screw	3	SS 304	0.77	5	13	-	See Average Fastener Results	
HAPR	**Average Fasteners**	246		82.02	23.89	34.15	-	~1500	See Table 5

Appendix E. ElaNa-17 Component List by CubeSat: IceCube
Appendix F.

CUBESAT	Name	Qty	Material	Mass (g) (total)	Diameter/ Width (mm)	Length (mm)	Height (mm)	Melting Temp	Comments
IceCube	IceCube	1	Various (see below)	4500	100	100	300	Low Melting Temp	Demise
IceCube	CubeSat Structure	1	Al 6061-T6	1052	100	100	300	Low Melting Temp	Demise
IceCube	Antennae	1	Al	110	98	98	7	Low Melting Temp	Demise
IceCube	Solar Panels	1	IPC-4101/99 FR4	928	500	300	300	Low Melting Temp	Demise
IceCube	Batteries Assembly (batt,board,etc)	1	Li-Ion Polymer, FR4	365	96	90	26	Low Melting Temp	Demise
IceCube	ADCS	1	Al, FR4	910	100	100	50	Low Melting Temp	Demise
IceCube	Comm Board	1	FR4, 1B31 Acrylic, DC 6-1104	260	96	90	1.6	Low Melting Temp	Demise
IceCube	C&DH Board	1	FR4	276	96	90	1.6	Low Melting Temp	Demise
IceCube	Fasteners	141	300/316 SS	133	4	6	-	1500	See Table 5
IceCube	Cabling	8	Copper alloy	103	n/a	n/a	n/a	Low Melting Temp	Demise
IceCube	Solder	n/a	Sn62 or Sn63 (Tin/Lead)	100	n/a	n/a	n/a	Low Melting Temp	Demise
IceCube	Miscelanea	n./a	Not expected to be high-temp materials	763	n/a	n/a	n/a	Low Melting Temp	Demise

Appendix G. ElaNa-17 Component List by CubeSat: OpenOrbiter1

CUBESAT	Name	Qty	Material	Mass (g) (total)	Diameter/ Width (mm)	Length (mm)	Height (mm)	Melting Temp	Comments
OpenOrbiter 1	OpenOrbiter 1	1	-		-	-	-	-	-
OpenOrbiter 1	CubeSat Structure *	1	Aluminum 6061	264.0	100	100	113.5	Low Melting Temp	Demise
OpenOrbiter 1	Antenna	1	COTS Steel (Tape Measure)	30	12.7	164.34	-	1500	See Table 5
OpenOrbiter 1	Solar Panel Board (+Z Face)**	1	2-Layer FR-4 1oz/ft^3	31.5	94.5	94.5	1.8669	Low Melting Temp	Demise
OpenOrbiter 1	Solar Panel Boards **	4	2-Layer FR-4 1oz/ft^3	119.1	83	100	1.8669	Low Melting Temp	Demise
OpenOrbiter 1	Sep Switches	3	COTS Plastic	1.5	5.8	12.7	5	Low Melting Temp	Demise
OpenOrbiter 1	Payload Camera Board**	1	Standard COTS Components	4.1	50	50	-	Low Melting Temp	Demise
OpenOrbiter 1	Batteries	4	Steel 304, LiNiCoAlO2	200	18.6	68	-	1450	See Table 5
OpenOrbiter 1	Electrical Power System Board **	1	Standard COTS Components	25.7	87	100	7.5803	Low Melting Temp	Demise
OpenOrbiter 1	Primary Flight Comp/ Comm Board **	1	Standard COTS Components	25.7	87	100	5	Low Melting Temp	Demise
OpenOrbiter 1	System Interconnect Board **	1	Standard COTS Components	25.7	92.8	92.8	5	Low Melting Temp	Demise
OpenOrbiter 1	Payload Board **	1	Standard COTS Components	25.7	87	100	5	Low Melting Temp	Demise
OpenOrbiter 1	ADCS Board **	1	Standard COTS Components	25.7	87	100	5	Low Melting Temp	Demise
OpenOrbiter 1	ADCS - Electromagnets Cores	3	Ferrite	42	7.62	-	63.5	Low Melting Temp	Demise
OpenOrbiter 1	ADCS - Motors	3	Copper, SS, Aluminum, ABS	135	19.2	-	9.8	Low Melting Temp	Demise
OpenOrbiter 1	Fasteners	97	Stainless Steel (dimensions are averaged over 97 fasteners)	53.8	2	4.84	-	Low Melting Temp	Demise
OpenOrbiter 1	Cabling	-	eg. Copper alloy	-	-	-	-	Low Melting Temp	Demise
OpenOrbiter 1	Epoxy	-	Adhesive	-	-	-	-	Low Melting Temp	Demise