March 15, 2013

Orbital Debris Assessment for COPPER on the ORS-3 / ELaNa-4 Mission per NASA-STD 8719.14A

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. *ORS-3 LV to IPS ICDORS-3 LV to IPS ICD* (Orbital Information), Orbital Document, #1047-0111 Rev Draft
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. *ORS-3 LV to IPS ICD*, Orbit Description, Orbital Document, #1047-0111 Rev Draft.
I. *UL Standard for Safety for Household and Commercial Batteries, UL 2054*. UL Standard. 2nd ed. Northbrook, IL, Underwriters Laboratories, 2005.
J. *Common Risk Criteria Standards for National Test Ranges*, Standard 321-10, December 2010.

The intent of this report is to satisfy the orbital debris requirements listed in ref. (a) for the COPPER auxiliary mission launching in conjunction with the ORS3 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 COPPER auxiliary payload mission flown on ORS3. COPPER as part of the ELaNa-4 mission is 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 2.8 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 COPPER mission

Section 1: Program Management and Mission Overview

The ELaNa-4 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:

COPPER: Point of Contact - Michael Swartwout, Principle Investigator

Program Milestone Schedule	
Task	**Date**
CubeSat Selection	5/16/12
CubeSat Build, Test, and Integration	1/1/12 through 7/1/13
MRR	7/1/13
CubeSat Delivery to KAFB	8/15/13
CubeSat Integration into P-PODs	8/15/13 through 8/20/13
Launch	9/30/13

Figure 1: Program Milestone Schedule

The ELaNa-4 mission will deploy 11 pico-satellites (or CubeSats) as a secondary payload on the ORS3 mission. The CubeSat slotted position is identified in Table 2. The ELaNa 4 manifest includes: Ho`oponopono-2, KySat-2, DragonSat-1, Trailblazer, ChargerSat, PhoneSat, Vermont Lunar Orbiter/Lander, COPPER, SwampSat, CAPE-2, and TJ3Sat.

Each CubeSat ranges in size from a 10 cm cube to 10 cm x 10cm x 30 cm, with masses from about 1 kg to 4 kg total. The CubeSats have been designed and built by a high school, universities, and government agencies and each has its own mission goals.

The ELaNa-4 mission will be launched as an auxiliary payload on the ORS3 mission on a Minotaur launch vehicle from Wallops Flight Facility, Virginia. The current launch date is 30 September, 2013. The eleven CubeSats will be ejected from P-POD carriers attached to the launch vehicle, placing the CubeSats in an orbit approximately 500 X 500 km at inclination of 40.5 deg (ref. (h)).

Section 2: Spacecraft Description

There are eleven CubeSats flying on the ELaNa-4 Mission. They will be deployed out of five P-PODs, as shown in Table 2 below.

Table 2: ELaNa-4 CubeSats

PPOD Slot	CubeSat Quantity	CubeSat size	CubeSat Names	CubeSat Masses (kg)
2.2	1	3U (10 cm X 10 cm X 30 cm)	Ho`oponopono-2	4
2.3A 2.3B	2	1U (10 cm X 10 cm X 10 cm) 1U (10 cm X 10 cm X 10 cm)	KySat-2 DragonSat-1	1.2 0.99
2.5 A 2.5 B 2.5 C	3	1U (10 cm X 10 cm X 10 cm) 1U (10 cm X 10 cm X 10 cm) 1U (10 cm X 10 cm X 10 cm)	Trailblazer ChargerSat PhoneSat	1.2 1 1.12
2.6 A 2.6 B	2	1U (10 cm X 10 cm X 10 cm) 1U (10 cm X 10 cm X 10 cm)	Vermont Lunar COPPER	1.01 1.25
2.7 A 2.7 B 2.7 C	3	1U (10 cm X 10 cm X 10 cm) 1U (10 cm X 10 cm X 10 cm) 1U (10 cm X 10 cm X 10 cm)	SwampSat CAPE-2 TJ3Sat	1.21 0.98 0.89

The following subsections contain description of the COPPER CubeSat.

COPPER CubeSat Description
St. Louis University – 1U

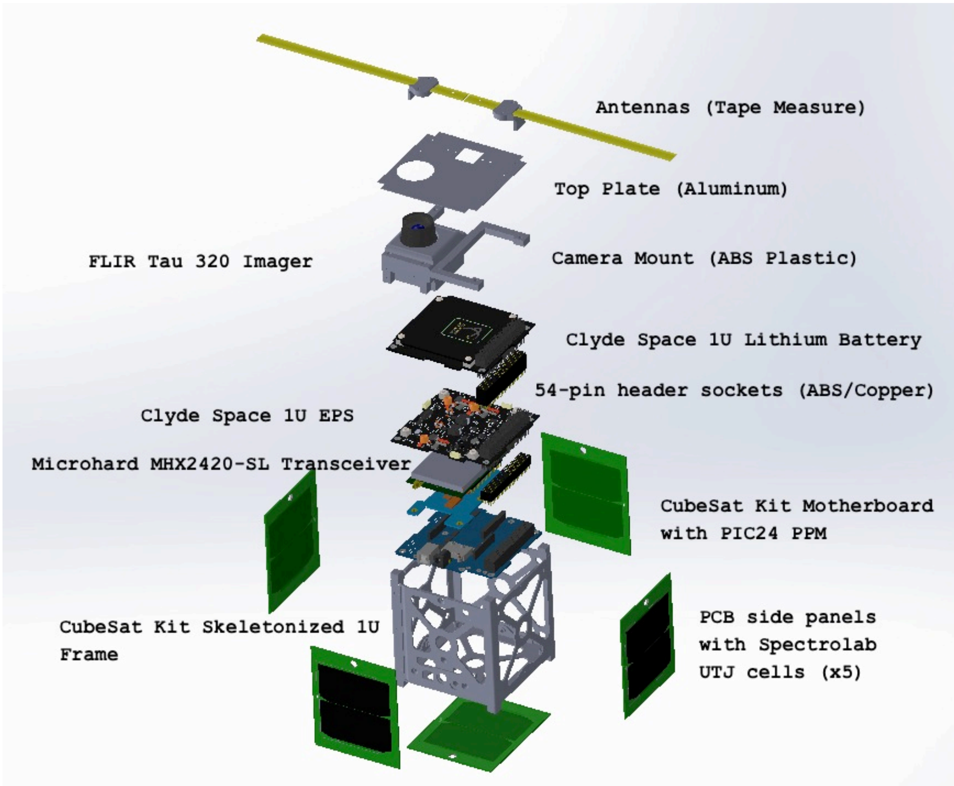

Figure 2: COPPER Expanded View

COPPER will characterize the use of a commercial off the shelf (COTS) long-wave infrared (LWIR) imager for on-orbit characterization of space systems and earth observation, capture post-separation sequence in LWIR, automatically identify image events, and flight-test a radiation effects monitoring payload for future missions.

Upon deployment from the P-POD, COPPER will power up and attempt to capture 30 fps video for 5 minutes. After 45 minutes the UHF antenna is deployed and the beacon is activated. After passively detumbling and establishing radio contact, the radiation sensor and imaging payloads will be activated.

The primary CubeSat structure is made of Aluminum 6061. 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-polymer batteries with over-charge/current protection circuitry. See Table 3 for UL Listing information.

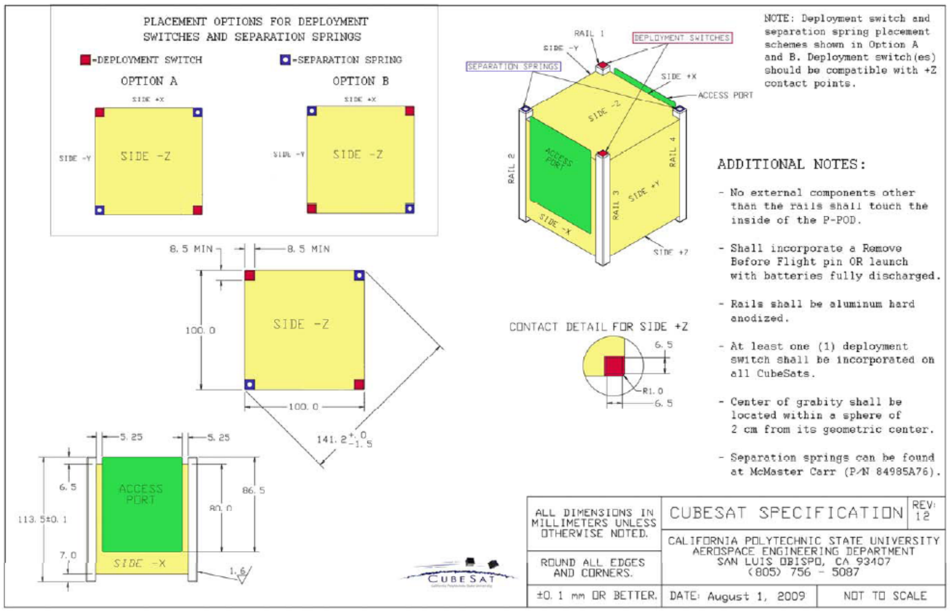

Figure 3: 1U CubeSat Specification

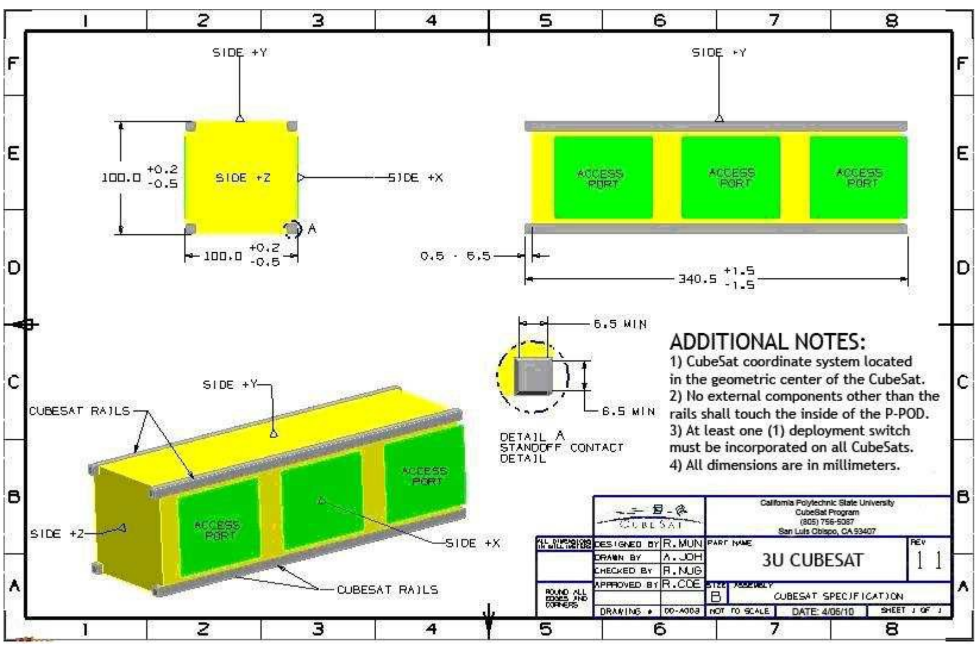

Figure 4: 3U CubeSat Specification

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 COPPER CubeSat mission therefore this section is not applicable.

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

Malfunction of lithium ion or lithium polymer batteries and/or associated control circuitry has been identified as a potential cause for spacecraft breakup during deployment and mission operations.

While no passivation of batteries will be attempted, natural degradation of the solar cell and battery properties will occur over the post mission period, which may be as long as 2.5 years. These conditions pose a possible increased chance of undesired battery energy release. The battery capacity for storage will degrade over time, possibly leading to changes in the acceptable charge rate for the cells. Individual cells may also change properties at different rates due to time degradation and temperature changes. The control circuit may also malfunction as a result of exposure to the space environment over long periods of time. The cell pressure relief vents could be blocked by small contaminants. Any of these individual or combined effects may theoretically cause an electro-chemical reaction that result in rapid energy release in the form of combustion.

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

Section 4 asks for a list of components, which shall be passivated at End of Mission (EOM), as well as the method of passivation and description of the components, which cannot be passivated. No passivation of components is planned at the End of Mission for any of the COPPER CubeSat.

Since the batteries used do not present a debris generation hazard even in the event of rapid energy release (see assessment directly below), passivation of the batteries is not necessary in order to meet the requirement 4.4-2 (56450) for passivation of energy sources "to a level which cannot cause an explosion or deflagration large enough to release orbital debris or break up the spacecraft." Because passivation is not necessary, and in the interest of not increasing the complexity of the CubeSats, there was no need to add this capability to their electrical power generation and storage systems.

Assessment of spacecraft compliance with Requirements 4.4-1 through 4.4-4 shows that the COPPER CubeSat is compliant. Requirements 4.4-3 and 4.4-4 are not applicable.

The following addresses requirement 4.4-2. COPPER has not been designed to disconnect onboard storage energy devices (lithium ion and lithium polymer batteries). However, the CubeSats batteries still meet Req. 56450 by virtue of the fact that they cannot "cause an explosion or deflagration large enough to release orbital debris or break up the spacecraft".

The battery cells utilize lithium ion technology and are compliant with Underwriters Laboratory (UL) Standard 1642.

Table 3: ELaNa-4 CubeSat Cells

CubeSat	Technology	Manufacturer	Model	UL Listing Number
COPPER	Li-Ion Polymer	VARTA	PLF503759	MH19896

The batteries are all consumer-oriented devices. All battery cells have been recognized as Underwriters Laboratories (UL) tested and approved. Furthermore, safety devices incorporated in these batteries include pressure release valves, over current charge protection and over current discharge protection.

The fact that these batteries are UL recognized indicates that they have passed the UL standard testing procedures that characterize their explosive potential. Of particular concern to NASA Req. 56450 is UL Standard 1642, which specifically deals with the testing of lithium batteries. Section 20 Projectile Test of UL 1642 (ref. (e)) subjects the test battery to heat by flame while within an aluminum and steel wire mesh octagonal box, "[where the test battery] shall remain on the screen until it explodes or the cell or battery has ignited and burned out"(UL 1642 20.5). To pass the test, "no part of an exploding cell or battery shall penetrate the wire screen such that some or all of the cell or battery protrudes through the screen" (UL 1642 20.1).

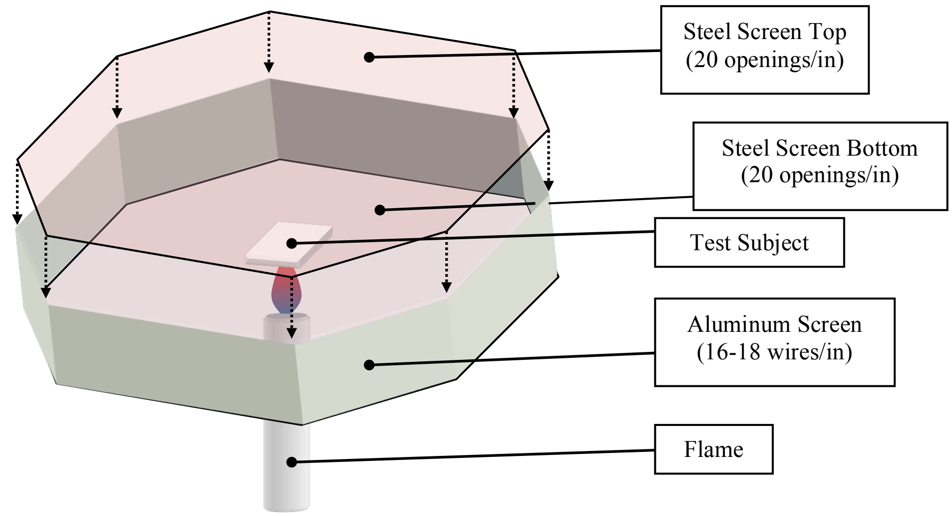

Figure 5: Underwriters Laboratory Explosion Test Apparatus

The batteries being launched via CubeSat will experience conditions on orbit that are generally much less severe that those seen during the UL test. While the source of failure would not be external heat on orbit, analysis of the expected mission thermal environment performed by NASA LSP Flight Analysis Division shows that given the very low (<=41.44 W-hr, maximum for PhoneSat) power dissipation for CubeSats, the batteries will be exposed to a maximum temperature that is well below their 212^{o}F safe operation limit (ref. (f)). It is unlikely but possible that the continual charging with 2 to 6 W of average power from the solar panels over an orbital life span greater than 2 years may expose the two to four batteries (per CubeSat) to overcharging which could cause similar heat to be generated internally. Through the UL testing, it has been shown that these batteries do not cause an explosion that would cause a fragmentation of the spacecraft.

A NASA Glenn Research Center guideline entitled Guidelines on Lithium-ion Battery Use in Space Applications (ref. (d)) explains that the hazards of Li-Ion cells in an overcharge situation result in the breakdown of the electrolyte found in Li-ion cells causing an increase in internal pressure, formation of flammable organic solvents, and the release of oxygen from the metal oxide structure. From a structural point of view a battery in an overcharge situation can expect breakage of cases, seals, mounting provisions, and internal components. The end result could be "unconstrained movement of the battery" (ref. (d), pg 13). This document clearly indicates that only battery deformation and the escape of combustible gasses will be seen in an overcharging situation, providing further support to the conclusion that CubeSat fragmentation due to explosion is not a credible scenario for this application. It is important to note that the NASA guide to Li-ion batteries makes no mention of these batteries causing explosions of any magnitude whatsoever.

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 thirteen CubeSats is that of the Ho`oponopono-2 CubeSat with antennas deployed (10 X 10 X 30 cm with one deployable antenna 2.3 X 500 cm):

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

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

COPPER evaluated for this ODAR is 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 COPPER .

Once a CubeSat has been ejected from the P-POD 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 COPPER orbit at deployment is 500 km apogee altitude by 500 km perigee altitude, with an inclination of 40.5 degrees. With an area to mass (4.0 kg) ratio of 0.011 m^2/kg, DAS yields 3.3 years for orbit lifetime for its stowed state, which in turn is used to obtain the collision probability. Even with the variation in CubeSat design and orbital lifetime ELaNa 4 CubeSats see an average of $10^{-7.7}$ probability of collision. Ho`oponopono-2 sees the highest probability of collision of $10^{-7.1}$. Table 4 below provides complete results.

Table 4: CubeSat Orbital Lifetime & Collision Probability

CubeSat COPPER

	Mass (kg)	1.25
Stowed	**Mean C/S Area (m^2)**	0.016
	Area-to Mass (m^2/kg)	0.013
	Orbital Lifetime (yrs)	2.8
	Probability of collision (10^X)	-7.6
Deployed	**Mean C/S Area (m^2)**	0.017
	Area-to Mass (m^2/kg)	0.014
	Orbital Lifetime (yrs)	2.4
	Probability of collision (10^X)	-7.5

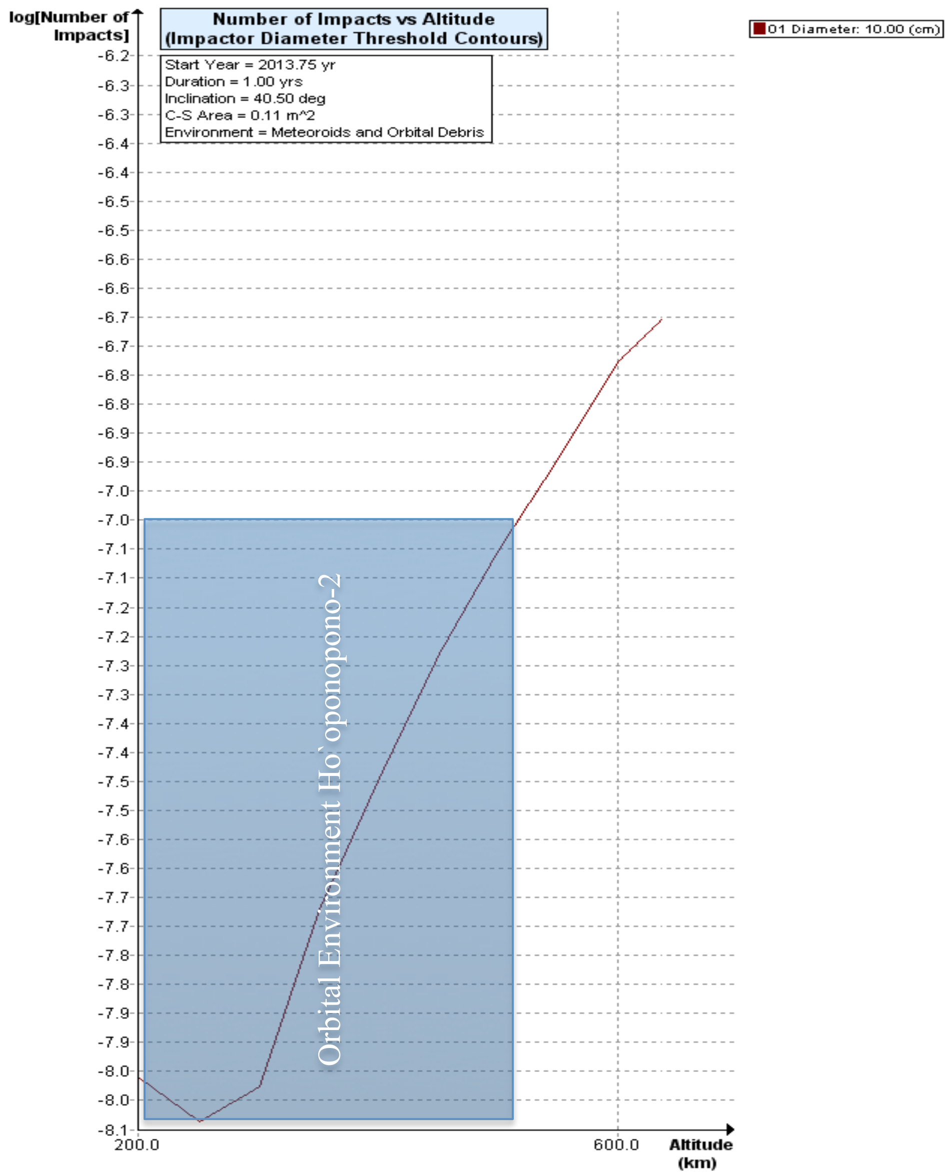

Figure 6: Highest Risk of Orbit Collision vs. Altitude (Ho`oponopono-2 Deployed)

The Ho`oponopono-2 deployed state is worst-case and bounds the COPPER deployed state.

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.

The probability of any ELaNa-4 spacecraft collision with debris and meteoroids greater than 10 cm in diameter and capable of preventing post-mission disposal is less than $10^{-7.0}$, 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 COPPER to be compliant. Requirement 4.5-2 is not applicable to this mission.

Section 6: Assessment of Spacecraft Postmission Disposal Plans and Procedures

COPPER 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.

The worst-case (smallest Area-to-Mass) post-mission disposal is COPPER in stowed configuration. The area-to-mass is calculated as follows:

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

Equation 3: Area to Mass

$$\frac{0.016\ m^2}{1.25\ kg} = 0.013\frac{m^2}{kg}$$

The assessment of the spacecraft illustrates it is compliant with Requirements 4.6-1 through 4.6-5.

DAS 2.0.2 Orbital Lifetime Calculations:

DAS inputs are: 500 km maximum perigee X 500 km maximum apogee altitudes with an inclination of 40.5 degrees at deployment in the year 2013. An area to mass ratio of 0.013 m^2/kg for the COPPER CubeSat was input. DAS 2.0.2 yields a 2.8 years orbit lifetime for COPPER in its stowed state.

This meets requirement 4.6-1.

Assessment results show compliance.

Section 7: Assessment of Spacecraft Reentry Hazards

A detailed assessment of the components to be flown on ELaNa-4 was performed. The assessment used DAS 2.0 to provide bounding analysis to characterize component's risk. DAS 2.0 is a conservative tool used by the NASA Orbital Debris Office to verify Requirement 4.7-1.

DAS employs a conservative analysis methodology to determine if a component will survive reentry. Since DAS does not explicitly model the oxidative or ablative heating that a given component will experience during reentry, it generally over-predicts component survivability. This is an especially relevant consideration for small components that are on the edge of survivability, particularly those that are predicted to survive with very low residual kinetic energy.

The following steps are used to identify and evaluate a component's potential reentry risk.

1. Low melting temperature (less than 1000 °C) components are identified as materials that will never survive reentry and pose no risk to human casualty. This is confirmed through DAS analysis that shows that 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 higher temperature materials are shown to pose negligible risk to human casualty through a bounding analysis of the highest temperature components. For the CubeSats comprising the ELaNa-4 mission, the material with the highest melting temperature is 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 5)

Table 5: ELaNa-4 Stainless Steel DAS Analysis

CubeSat	ELaNa-4 Stainless Steel Components	Mass (g)	Length / Diameter (cm)	Width (cm)	Height (cm)		Demise Alt (km)	KE (J)
COPPER	UHF Antenna	4.6	1.24	19.05	0.124		0	<1

The majority of stainless steel components demise upon reentry. For ELaNa-4, the components that DAS conservatively identifies as reaching the ground have one joule of kinetic energy or less, far below the fifteen joule threshold. Since any injury incurred or inflicted by an object with such low energy would be negligible and would not require the individual to seek medical attention, these objects pose no risk of human casualty as defined by the Range Commander's Counsel in ref (j).

Through the method described above, Table 5, and the full component list in the Appendix, the COPPER CubeSat launching under the ELaNa 4 mission is 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 components.

Section 8: Assessment for Tether Missions

COPPER will not be deploying any tethers.

COPPER satisfies 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-G2/Mr. Atkinson
VA-C/Mr. Skrobot
VA-G2/Mr. Poffenberger
CP-02/Mr. Higginbotham
SA-D2/Mr. Frattin
SA-D2/Mr. Hale
SA-D2/Mr. Villa
AIS-22/Ms. Nighswonger

Appendix Index:

Appendix A. COPPER Component List

Row Number	Name	External/Internal (Major/Minor Components)	Qty	Material	Body Type	Mass (g)	Diameter/ Width (mm)	Length (mm)	Height (mm)	Low Melting Temp	Melting Temp	Comment
1	CubeSat Structure		1	Aluminum 6061	Box	122	100.0	100.0	110.0	Y		
2	Camera Support Structure		1	ABSPlus and Aluminum 6061	Box	50	53.5	42.1	37.4	Y		
3	Solar Panel Boards		6	PCB	Box	20	100.0	83.0	2.0	Y		
4	Solar Cells		8	Germanium, Gallium Arsenide, and Gallium Indium Diphosphorous	Plate	3.25	38.5	68.5	0.5	High Melt	1238	Negligible Risk, bounded by larger SS components. See Table 5
5	UHF Antenna		1	Mylar-coated Steel	Plate	4.6	12.4	190.5	0.0	High Melt	1454	Negligible Risk: KE ~ 0 J See Table 5.
6	S-Band Antenna		1	---	Plate	4	38.0	38.0	0.0	Y		
7	UHF Antenna Support Structure		5	ABSPlus	Plate	5	20.0	20.0	0.0	Y		
8	Solar Cell Adhesive / NuSil SCV1-2596		1	Conductive CV Silicone Elastomer Adhesive	Describe in Other Shape	0	N/A	N/A	N/A	Y		
9	Separation Switches		1	N/D	Other-Describe in Other Shape	5	N/A	N/A	N/A	Y		
10	Separation Springs		2	N/D	Other-Describe in Other Shape	1	N/A	N/A	N/A	Y		
11	UHF Antenna Deployment Fishing Wire		2	High Density Polyethylene and Nichrome wire	Cylinder	1	0.3	0.0	50.0	Y		
12	Payload FPGA Board		1	PCB	Box	55	93.4	37.3	38.3	Y		
13	Camera Body (mass includes camera lens)		1	Aluminum 6061	Box	70	41.1	36.6	33.8	Y		
14	Camera Lens		1	HAR-coated Silicon Window, Karonite / Epoxy- lens flange	Cylinder	0	19.0	0.0	18.8	Y		
15	Payload SD Card		1	N/D	Box	2	27.8	7.4	8.6	Y		
16	Battery		1	Lithium Ion Polymer Battery Cell	Box	83	N/A	N/A	N/A	Y		
17	Battery Board		1	PCB	Box	86	92.5	38.2	37.2	Y		
18	CDH Motherboard		1	PCB	Box	77	93.0	39.8	38.5	Y		
19	CDH Processor Board		1	PCB	Box	11	54.2	20.4	20.2	Y		

23	ADC Magnets		2	Neodymium (NdFeB) Magnets Grade N42	Box	15	6.0	12.2	12.2	High Melt	1300	Negligible Risk, bounded by larger SS components. See Table 5.
24	ADC Hysteresis Rods		1	HY-MU 80	Cylinder	50	N/A	N/A	N/A	High Melt	1454	Negligible Risk, bounded by larger SS components. See Table 5
25	UHF Radio Board Support Structure		4	ABSPlus	Box	23	N/A	N/A	N/A	Y		
26	Camera Nut		1	Steel	Cylinder	75	N/A	N/A	N/A	High Melt	1500	Negligible Risk, bounded by larger SS components. See Table 5
27	Payload Radiation Board		1	PCB	Box	35.6	90.0	95.0	1.5	Y		
28	Roll Rate Gyro Board		1	PCB	Box	1	16.2	6.1	6.9	Y		
29	Standoffs		20	Aluminum 7075-T6	Cylinder	2	6.4	N/A	N/A	Y		
30	Fasteners		20	Aluminum 6061	Cylinder	0.25	N/A	N/A	N/A	Y		
31	Cabling		6	Copper Cabling	Other-Describe in Other Shape Section	2	N/A	N/A	N/A	Y		
32	Kapton Tape		1	DuPont Kapton FPC Polyimide Film	Other-Describe in Other Shape Section	50	N/A	N/A	N/A	Y		
33	FPGA Solder		1	Low Outgassing Solder	Other-Describe in Other Shape Section	1	N/A	N/A	N/A	Y		
34	CubeSat Kit Bus Connector		4	Vectra E-130i, Copper	Box	10.3	26.1	9.3	23.9	Y		
35	Silicone Elastomer Sealant Paste/Dow Corning 6-1104		1	Dimethyl Siloxane, Methyldimethyoxy-terminated	Other-Describe in Other Shape Section	50	N/A	N/A	N/A	Y		
36	TASC Solar Cells		4	Germanium, Gallium Arsenide, and Gallium Indium Diphosphorous	Plate	0.18	N/A	N/A	N/A	High Melt	1238	Negligible Risk, bounded by larger SS components. See Table 5