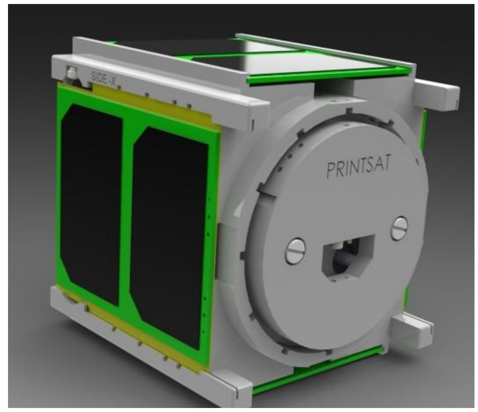
PrintSat



Orbital Debris Assessment Report

Doc #: PS-A-5003 Rev 1.0

Prepared By: Nathan Fite

Date: 4/13/2013

Montana State University
Colorado Satellite Services
Project Starshine
Kentucky Space

THIS PAGE LEFT INTENTIONALLY BLANK

CERTIFICATION LOG

(Signature on file)

Nathan Fite Date
Author/RE

Reviewed:

(Signature on file)

Jim White Date
Systems Engineer

Approval:

(Signature on file)

Ehson Mosleh Date
Systems Engineer

1.0 **Revision Log**

Rev.	Area(s) Affected	Date	Approval
1.0	Initial	4/13/2013	Nathan Fite

2.0 Scope and Overview

This document is derived from the *Orbital Debris Assessment for the CubeSats on the ORS-4/ELaNa-7 Mission per NASA-STD 8719.14A* document provided by NASA LSP. All data was captured directly from this document.

This document is intended to illustrate the compliance of the PrintSat spacecraft with the orbital debris requirements of the ORS-4, ELaNa-7 mission.

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 3.7 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-7 mission

Table 1: Orbital Debris Requirement Compliance Matrix

3.0 Applicable Documents

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-4 Delta Mission Kickoff Meeting, Operationally Responsive Space, March 6, 2013.
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. *UL Standard for Safety for Household and Commercial Batteries, UL 2054*. UL Standard. 2nd ed. Northbrook, IL, Underwriters Laboratories, 2005
I. *Common Risk Criteria Standards for National Test Ranges*, Standard 321-10, December 2010.

4.0 Program Management

The ELaNa-7 mission is sponsored by the Space Operations Mission Directorate at NASA Headquarters. The PrintSat Program Management is as follows:

Principle Investigator – Dr. David Klumpar
Affiliation: Montana State University Space Science and Engineering Lab

Project Manager – Nathan Fite
Affiliation: Montana State University Space Science and Engineering Lab

5.0 Mission Overview

There are eleven pico-satellites (or CubeSats) flying on the ORS-4 Mission, two of which are manifested under the ELaNa-7 mission: PrintSat and ArgusSat-1. The ELaNa-7 mission will deploy these spacecraft from the NLAS (Nano-Sat Launch Adapter System) dispenser as a secondary payload on the ORS-4 mission.

The ELaNa-7 mission will be launched as an auxiliary payload on the ORS-4 mission on a Super Strypi launch vehicle from Pacific Missile Range Facility, Kauai. The current launch date is October 30th, 2013. The two CubeSats will be ejected from the NLAS carrier attached to the launch vehicle, placing the CubeSats in an orbit approximately 410 X 485 km at inclination of 91 deg. Recent changes in launch trajectory have moved this orbit from 450 x 525km at 97 deg inclination, for which this ODAR has been executed. The *Orbital Debris Assessment for the CubeSats on the ORS-4/ELaNa-7 Mission per NASA-STD 8719.14A* document in which this PS-A-5003 is derivative, will remain the overriding analysis under the presumption by NASA that the new orbit will decay more quickly.

This ODAR is conservative due to a recent change in orbital trajectory. The orbit was changed from orbit, to 410 x 410km and 91˚ inclination.

The PrintSat CubeSat is a 1U, 10 cm cube with a mass of 0.9kg.

Size	Mass
10cm x 10cm x 10cm	0.9kg

Table 2: PrintSat Size and Mass

Program Milestone Schedule	
Task	**Date**
CubeSat Selection	11/2012
CubeSat Build, Test, and Integration	11/2012 to 7/12/2013
MRR	7/13/2013
CubeSat Delivery to KAFB	9/6/2013
CubeSat Integration into NLAS	9/6/2013 to 9/13/2013
Launch	10/30/13

Table 3: ELaNa-7 Milestones

6.0 PrintSat Mission Description

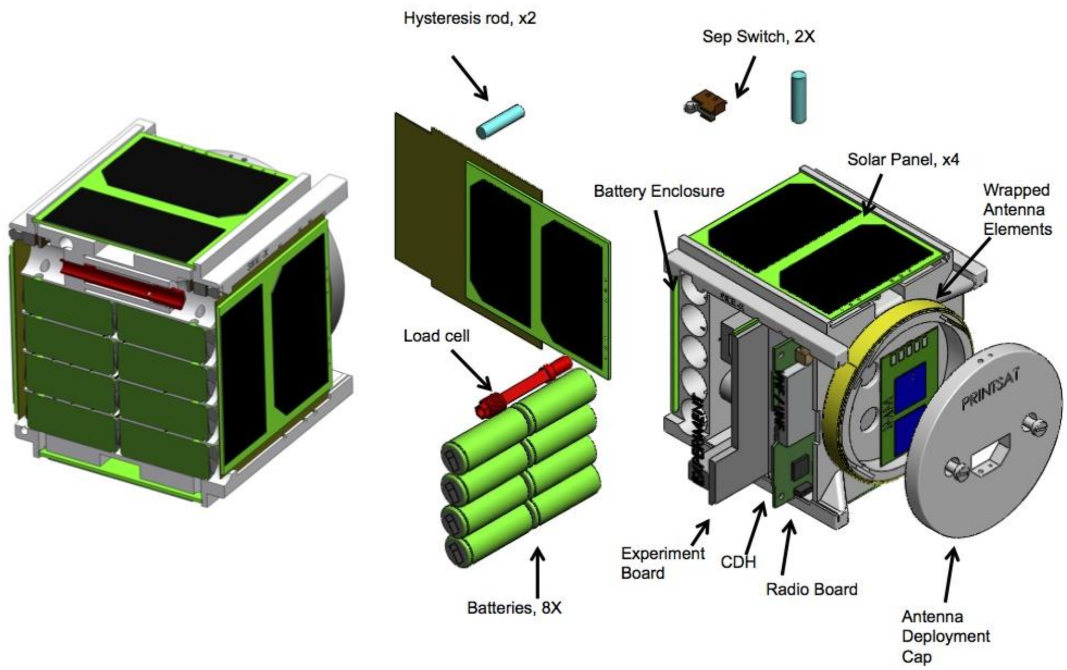


Figure 1: PrintSat Expanded View

PrintSat is a 1U CubeSat that demonstrates the utility of using Additive Manufacturing (aka 3D printing) for space structures and mechanisms. The structure is printed from Windform XT2.0 material. PrintSat will measure the performance of that material during a nominal 1-year mission life, possibly extended beyond that time. Earthbound measurements will be made on an identical structure during the mission to allow comparisons. The manufacturing and testing process is being documented so advantages and issues can be published.

After 45 minutes from NLAS separation, the PrintSat antenna will be deployed and beacon will start transmitting. For the first couple weeks, the ground station team will attempt to make contact and differentiate between objects. For the next 3 years, the performance of the WindFormXT material will be evaluated and compared to other units.

The primary CubeSat structure is made of WindFormXT 2.0. All exterior surfaces, with the exception of the rails, will be gold-plated. PrintSat otherwise 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 nickel-cadmium batteries with over-charge/current protection circuitry.

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-7 CubeSat mission therefore this section is not applicable.

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

Note: This entire section applies to all eleven of the CubeSats on the ORS-4/ELaNa-7 mission.

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 ELaNa-7 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 ELaNa-7 CubeSats.

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 ELaNa-7 CubeSats are compliant. Requirements 4.4-3 and 4.4-4 are not applicable.

The following addresses requirement 4.4-2. The CubeSats that have been selected to fly on the ORS-4 mission have not been designed to disconnect their 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 batteries used in the eleven CubeSats are of similar manufacture, design, and performance. Ten of the battery cells utilize lithium ion technology and are compliant with Underwriters Laboratory (UL) Standard 1642. The remaining one utilizes nickel metal hydride technologies and complies with Air Force standards for space flight acceptability. In general, these batteries are similar in size and power to cell phone batteries.

CubeSat	Technology	Manufactor	Model	UL Listing Number
PrintSat	NiCd	JJJ Battery	J-4/5A1200B	MH29258

Table 4: PrintSat Spacecraft Cells

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. For lithium batteries UL Standard 1642, which specifically deals with the testing of lithium batteries while UL Standard 2041, deals with NiCd and NiMh 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).

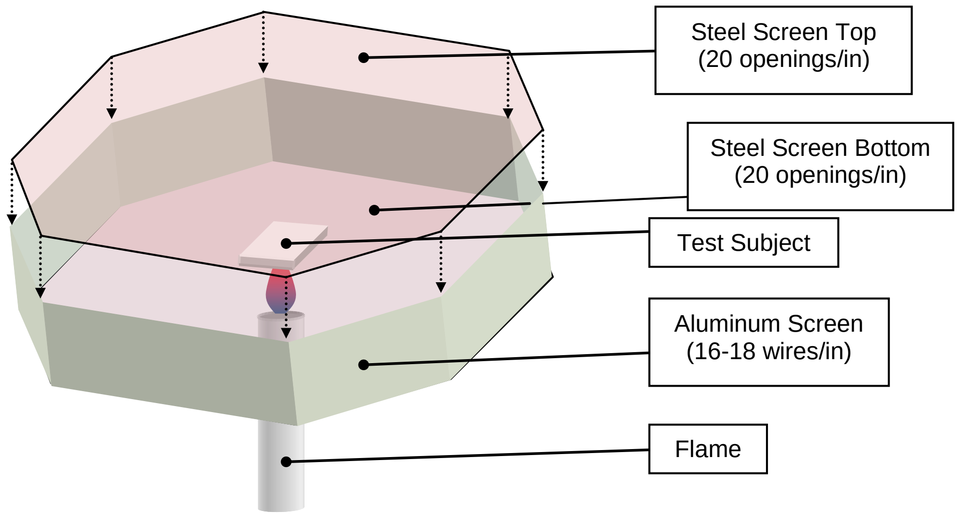


Figure 2: Underwriters Laboratory Explosion Test Apparatus

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 a 1U) 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.

The PrintSat batteries are based on NiCd technologies and has been UL certified to UL 2041 standard (ref (i)). The UL 2041 standard applies the same destructive testing previously discussed for Li-Ion cells. Through a combination of UL certification and an understanding of the general behavior of the failure modes associated with these types of batteries (ref. (d)) it is possible to conclude that Requirement 56450 is satisfied by these batteries as well. Specifically, these batteries will "not cause an explosion or deflagration large enough to release orbital debris or break up the spacecraft" (Requirement 56450).

7.0 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) of the two CubeSats is that of the Argus CubeSat with antennas deployed (10 X 10 X 21 cm with two deployable antenna 1 X 15cm):

Equation 1: Mean Cross Sectional Area for Convex Objects

Equation 2: Mean Cross Sectional Area for Complex Objects

Both 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 NLAS 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 Argus orbit at deployment is 525 km apogee altitude by 450 km perigee altitude, with an inclination of 97 degrees. With an area to mass (2.66 kg) ratio of 0.0083 m^2/kg, DAS yields 3.7 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-7 CubeSats see an average of $10^{-7.2}$ probability of collision. Argus in it's stowed state sees the highest probability of collision of $10^{-6.9}$. Table 4 below provides complete results.

Table 5: CubeSat Orbital Lifetime & Collision Probability

	CubeSat	Argus	PrintSat
	Mass	2.66	0.9
Stowed	**Mean C/S Area (m^2)**	0.0208	0.0163
	Area-to Mass (m^2/kg)	0.0083	0.0181
	Orbital Lifetime (yrs)	3.7	1.3
	Probability of collision (10^X)	-6.875	-7.4500
Deployed	**Mean C/S Area (m^2)**	0.0293	0.0200
	Area-to Mass (m^2/kg)	0.0117	0.0222
	Orbital Lifetime (yrs)	2.1	1.0
	Probability of collision (10^X)	-7	-7.5

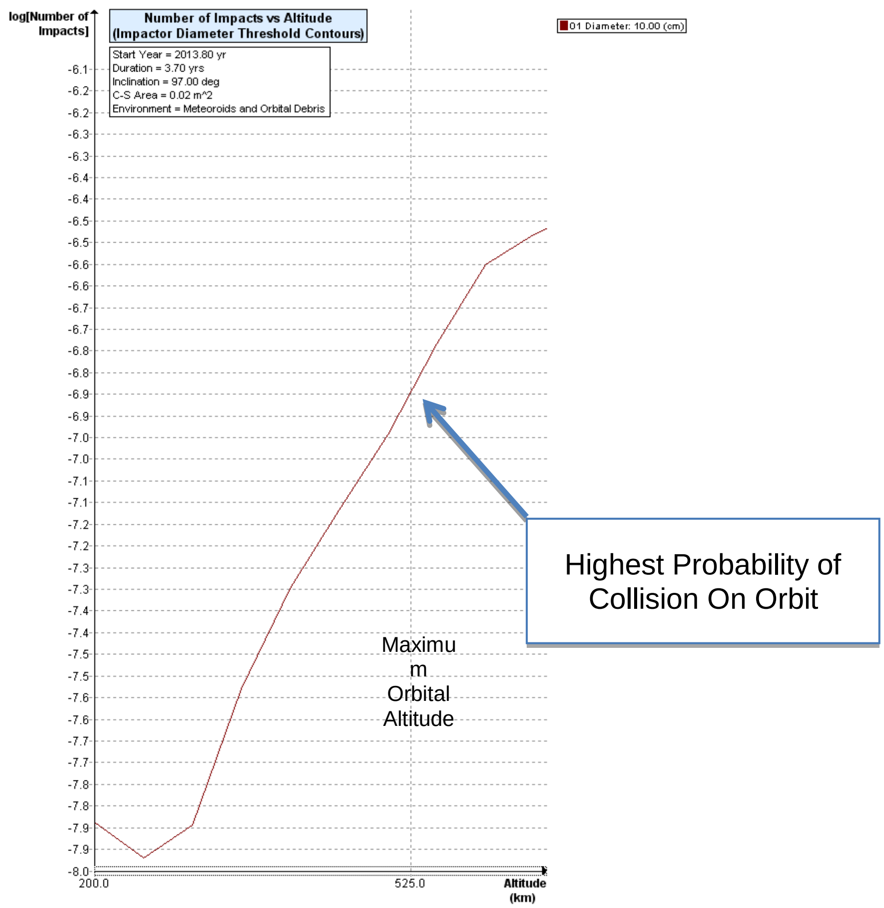


Figure 3: Highest Risk of Orbit Collision vs. Altitude (Argus Stowed)

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-7 spacecraft collision with debris and meteoroids greater than 10 cm in diameter and capable of preventing post-mission disposal is less than $10^{-6.875}$, 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-7 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-7 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 Argus in its stowed configuration as the worst case. The area-to-mass is calculated for is as follows:

Equation 3: Area to Mass

Argus 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: 450 km maximum perigee X 525 km maximum apogee altitudes with an inclination of 97 degrees at deployment in October of the year 2013. An area to mass ratio of 0.0083 m^2/kg for the Argus CubeSat was imputed. DAS 2.0.2 yields a 3.7 years orbit lifetime for Argus in its stowed state.

This meets requirement 4.6-1. For the complete list of CubeSat orbital lifetimes reference **Table 5: 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-7 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 **Error! Reference source not found.**.

CubeSat	ELaNa-7 Stainless Steel Components	Mass (g)	Length / Diameter (cm)	Width (cm)	Height (cm)		Demise Alt (km)	KE (J)
PrintSat								
	2m Antenna Element	1	1.016	0.012	200		78	0
	7cm Antenna Element	1	1.016	0.012	7		0	0
	Batteries*	10	1.651	4.332	1.651		0	2
	ADCS Components*	15	0.318	0.318	0.318		0	0
	Fasteners	0.5	0.218	0.218	0.635		77.2	0
	Hysteresis Rods*	7	0.635	2.54	0.635		73.6	0

Table 6: ELaNa-7 Stainless Steel DAS Analysis

* Components modeled as Steel

To simplify the analysis any high temperature components with melting temperatures below that of steel were modeled as steel in order to provide a conservative analysis. The PrintSat battery uses NiCd chemistry. Cadmium has a melting temperature of ~300C while nickel melts around 1400C. The entire battery was modeled as steel providing an overly conservative analysis. In all likelihood will have less than 2 J of energy upon reentry.

The majority of stainless steel components demise upon reentry. The components that

DAS conservatively identifies as reaching the ground have 2 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 ref (i). 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 6: ELaNa-7 Stainless Steel DAS Analysis, and the full component lists in the Appendix all CubeSats launching under the ELaNa-7 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-7 CubeSats will not be deploying any tethers.

ELaNa-7 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.

Additional questions can be directed to 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
SA-D2/Mr. Hidago
AIS-22/Ms. Nighswonger

8.0 Appendix Index:

Appendix A. ELaNa-7 Component List by CubeSat: PrintSat

CubeSat	Row Number	Name	External/Internal (Major/Minor Components)	Qty	Material	Body Type	Mass (g)	Diameter/ Width (mm)	Length (mm)	Height (mm)	Low Melting	Melting Temp (C)	Comment
PrintSat	1	CubeSat Name	PrintSat										Demises
PrintSat	2	CubeSat Structure	0.02mm Nickel Plating	1	Windform XT2.0	Box	225	100	100	113.5	y	179	3D Printed Material Demises
PrintSat	3	2m Antenna Element	SMA RF Conn	1	Spring Steel (SS 410)		1	10.16	0.12	2000	n	1500	Demises See **Error! Reference source not found.**
PrintSat	4	7cm Antenna Element	SMA RF Conn	1	Spring Steel (SS 410)		1	10.16	0.12	70	n	1500	Negligible Risk: KE ~ 0 J See **Error! Reference source not found.**.
PrintSat	5	Solar Panels	Solar Cells, Thermistor, Interconnects	4	FR4	Rectangle	3	77.47	1.78	93.98	y		Demises
PrintSat	6	Sep Switches	Rocker Arm	2	Phenolic (Housing)	Polygon	1	12.7	5.08	9.14	y		Demises
PrintSat	7	Antenna Deployment Cap	Nichrome Burn wire, Nickel Plating (0.02mm)	1	Windform XT2.0	Cylinder	12	95.25	8.55	95.25	y		Demises
PrintSat	8	Batteries	Solder tabs	8	NiCd	Cylinder	10	16.51	43.32	16.51	n	1453	Negligible Risk: KE ~ 2 J See **Error! Reference source not found.**.
PrintSat	9	ADCS Components*	Located on Experiment Board	1	Neodynium - N52	Cylinder	15	3.18	3.18	3.18	n	1300	Negligible Risk: KE ~ 0 J See **Error! Reference source not found.**.
PrintSat	10	Exp Board Payload	Teledyne uDOS001-C, Magnet Housing	1	FR4	Polygon	75	95.89	12.38	90.17	y		Demises
PrintSat	11	He-100 Comm Board	Aluminum RF shield, 52-pin connector, MSP430	1	FR4	Polygon	95	96	7.1	90.28	y		Demises
PrintSat	12	Battery Board	n/a	n/a	Windform XT2.0	n/a	n/a	n/a	n/a	n/a	y		Demises
PrintSat	13	Custom C&DH Board	ATMEGA	1		Rectangle	80	95.89	15.18	90.17	y		Demises
PrintSat	14	Fasteners	ANSI Inch #2 Screw	8	SS 316	Socket Cap Screw	0.5	2.18	2.18	6.35	n	1500	Demises See **Error! Reference source not found.**

PrintSat			ANSI Inch #6 Screw	4	Polypropylene	Socket Cap Screw	0.25	3.43	3.43	6.35	y		Demises
PrintSat	15	Cabling	26 AWG Teflon jacket	~900mm	Teflon jacket, Copper conductor	Cable	10	1.3	1.3	900	y		Demises
PrintSat	16	Coax Cables	RG-178 Telfon jacket, Teflon dielectric	2	Teflon dielectric, Teflon jacket	Cable	5	1.8	1.8	177.8	y		Demises
PrintSat	17	Nichrome Burn Wire		1	Nichrome	Cylinder	0.2	0.2	0.2	150	**y**		Demises
PrintSat	18	Load Cell		1	Aluminum 7075-T6	Cylinder	5	9.4	57.28	9.4	y		Demises
PrintSat	19	Hysteresis Rods*		2	HyMu80	Cylinder	7	6.35	25.4	6.35	n	1454	Demises See **Error! Reference source not found.**