ELVL-2014-0043834
September 2, 2014

Orbital Debris Assessment for The CubeSats on the ULTRASAT /ELaNa-11 Mission per NASA-STD 8719.14A

Sensitive But Unclassified (SBU)

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Reply to Attn of: VA-H1 September 2, 2014

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-11 Mission

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. "CubeSat Orbit Lifetime – Initial Condition", ABC/ULTRASAT Gate #1 Review Meeting; ULA, April 16, 2014
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. 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-11 auxiliary mission launching in conjunction with the ULTRASAT 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.

Table 1 summarizes the compliance status of the ELaNa-11 auxiliary payload mission flown on the ULTRASAT mission. The single CubeSat comprising the ELaNa-11 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	Minimal risk to orbital environment, mitigated by orbital lifetime.
4.4-2	Compliant	Minimal risk to orbital environment, mitigated by orbital lifetime.
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 5.3 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-11 mission

Section 1: Program Management and Mission Overview

The ELaNa-11 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:

LightSail-A: Bruce Yost, Principle Investigator; Riki Munakata, Project Manager

Program Milestone Schedule	
Task	**Date**
CubeSat Selection	8/27/2013
CubeSat Build, Test, and Integration	11/1/2014
MRR	12/2/2014
Pre-Ship Review	N/A
CubeSat Delivery to CalPoly	1/5/2015
CubeSat Integration into P-PODs	1/6/2015
Launch	5/6/2015

Table 2: Program Milestone Schedule

The ELaNa-11 mission will be launched as an auxiliary payload on the ULTRASAT mission on an Atlas V launch vehicle from CCAFS, Fl. The ELaNa-11, will deploy 1 pico-satellite (or CubeSat). The CubeSat slotted position is identified in Table 3: ELaNa-11 CubeSats. ELaNa-11 manifests LightSail-A. The current launch date is in May 2015. The CubeSat LightSail-A will be ejected from a P-POD carrier attached to the launch vehicle, placing the CubeSats in an orbit approximately 342 x 700 km at inclination of 55 deg (ref. (c)).

LightSail-A is a 3U CubeSat (10 cm x 10cm x 34 cm), with mass of 4.85 kg total. The CubeSats have been designed and universities and government agencies and each have their own mission goals.

Section 2: Spacecraft Description

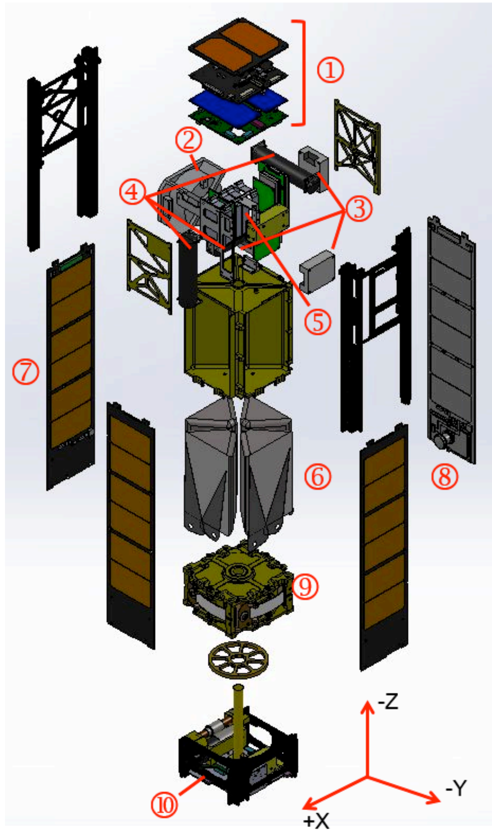
There is one CubeSat flying on the ELaNa-11 mission. It will be deployed out of a P-POD, as shown in Table 3: ELaNa-11 CubeSats below.

Table 3: ELaNa-11 CubeSats

P-POD Slot	CubeSat Quantity	CubeSat size	CubeSat Names	CubeSat Masses (kg)
1	1	3U (10cm X 10cm X 34cm)	LightSail-A	4.85

The following is a CubeSat description provided by the project.

LightSail-A – The Planetary Society – 3U CubeSat



No.	Subsystem
1	Avionics
2	Momentum Wheel Mass Model
3	Gyros
4	Torque Rods
5	Battery Module
6	Stowed Solar Sail
7	Solar Panel
8	Camera
9	Sail Deployer
10	Antenna

Figure 1: LightSail-A Expanded View

LightSail-A shown in Figure 1, is the first of two privately developed solar sail projects conceived and led by The Planetary Society. It will validate the spacecraft design and subsystem functional operation as well as deployment of a ~32 m^2 Mylar sail as a precursor to a more ambitious LightSail-B mission. Partners include Stellar Exploration, Inc., Cal Poly SLO and Ecliptic Enterprises Corporation.

Upon ejection from the P-POD, LightSail-A will begin the boot-up sequence. After successful completion of boot-up sequence, the unit will start up the ACS and go into detumble mode. At 45 minutes after ejection, the antenna will deploy and UHF beacon will commence shortly after. The ground team will acquire and track LightSail-A for approximately 2 weeks, verifying all parameters are within tolerance. After 2 weeks, the solar panels will be deployed. A day after the solar panels are deployed, the 32 m^2 solar sail will be deployed. We expect mission success 2 days after solar sail deployment: verify successful deployment, downlink image, and track orbital change. LightSail-A will deorbit several weeks after.

The CubeSat structure is made of Aluminum 6061-T6. It contains all standard commercial off the shelf (COTS) materials, electrical components, PCBs and solar cells. The payload consists of a 32 m^2 mylar solar sail with a custom metal boom.

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. The batteries are not UL listed, however the batteries will be tested per AFSPCMAN 91-710 to ensure compliance with safety requirements.

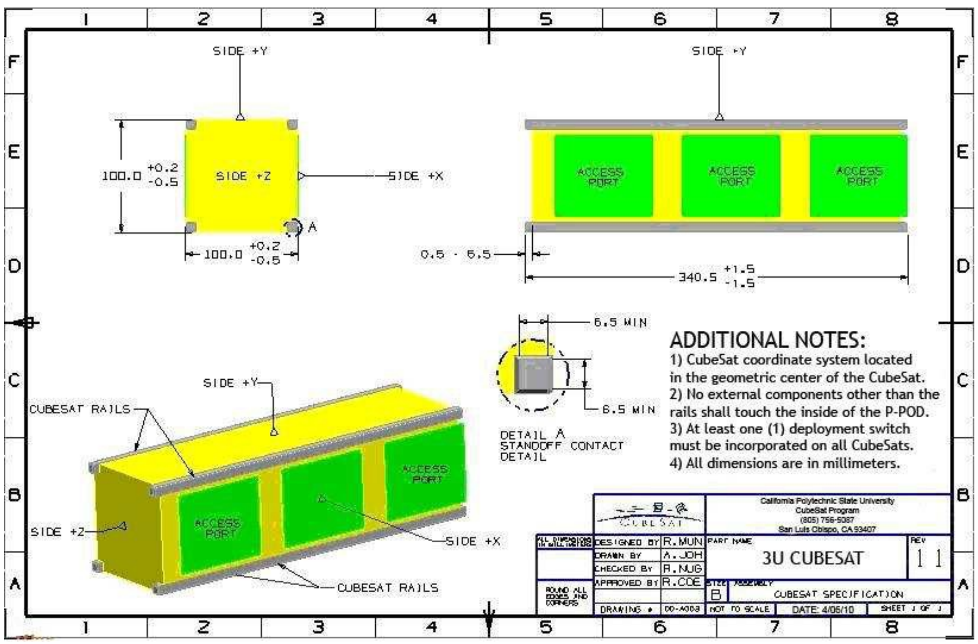


Figure 2: 3U CubeSat Specification

Section 3: Assessment of Spacecraft Debris Released during Normal Operations

No releases are planned on the ELaNa-11 CubeSat mission therefore this section is not applicable.

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.

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.

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-11 mission. No passivation of components is planned at the End of Mission for the LightSail-A CubeSat.

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 (i)).

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. (i))

Assessment of spacecraft compliance with Requirements 4.4-1 through 4.4-4 shows that with a lifetime of 5.3 years maximum the ELaNa-11 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) of LightSail-A is when it is fully deployed with antennas and solar sail deployed (10cm x 10cm x 34cm with four deployable solar panels 7.8cm x 32 cm and a deployable solar sail 557cm x 557cm):

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

Equation 1: Mean Cross Sectional Area for Convex Objects

The LightSail-A CubeSat 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 lifetimes.

LightSail-A will be in the stowed configuration immediately after being ejected from the P-POD. After two weeks the solar panels deploy and detumble operations begin. While the CubeSat is tumbling Equation 1 is valid. Once attitude control has been established cross sectional area is now determined by what surface area is exposed normal to the velocity vector.

LightSail-A operations dictate that the CubeSat's Z axis will be aligned with the earth's magnetic field (nadir point the antenna). This configuration results in the large solar sail being edge on to the velocity vector (+/- 15 degrees).

In determining the cross sectional area used in the DAS (Debris Assessment Software) analysis various orientations and configurations were considered. While stowed and tumbling the average cross sectional area is approximated ¼ the total surface area (ref (b)). During the operation mode the largest cross sectional area exposed to the velocity vector results when the 15 degree offset causes the solar sail to have an effective height of 144 cm and width of 557 cm. In the worst case orbit lifetime scenario the full solar sail is presented to the velocity vector. In both operational and worst case modes the solar sail obscures the additional CubeSat geometry.

The LightSail-A orbit at deployment is 700 km apogee altitude by 342 km perigee altitude, with an inclination of 55 degrees. With an area to mass (4.85 kg) ratio of 0.0081 m^2/kg. In the stowed configuration, DAS yields 5.3 years for orbit lifetime, which in turn is used to obtain the collision probability. The stowed LightSail-A will see a probability of collision with large objects of $0x10^{-5}$ and a fully operational LightSail-A sees a probability of collision of $1x10^{-5}$. Table 4 below provides complete results.

Table 4: CubeSat Orbital Lifetime & Collision Probability

	Configuration	Stowed[1]	Operational[2]	Worst Case[3]
	Mass (kg)	4.85	4.85	4.85
LightSail-A	**C/S Area (m^2)**	0.039[4]	8.0	31.0
	Area-to Mass (m^2/kg)	0.008	1.7	6.4
	Orbital Lifetime	5.3 yrs	~ 6 days	> 1day
	Probability of collision	0x10^-5	1x10^-5	2x10^-5

1. Stowed configuration is in a tumble as deployed from P-POD without any deployed components.
2. Operational attitude indicates fully deployed solar sail and solar panels with ACS stabilized +/- 15 degree of Z-axis from nadir. The solar sail is edge on to the velocity vector +/- 15 degrees.
3. Worst Case configuration presents the solar sail normal to the velocity vector.
4. Mean cross sectional area.

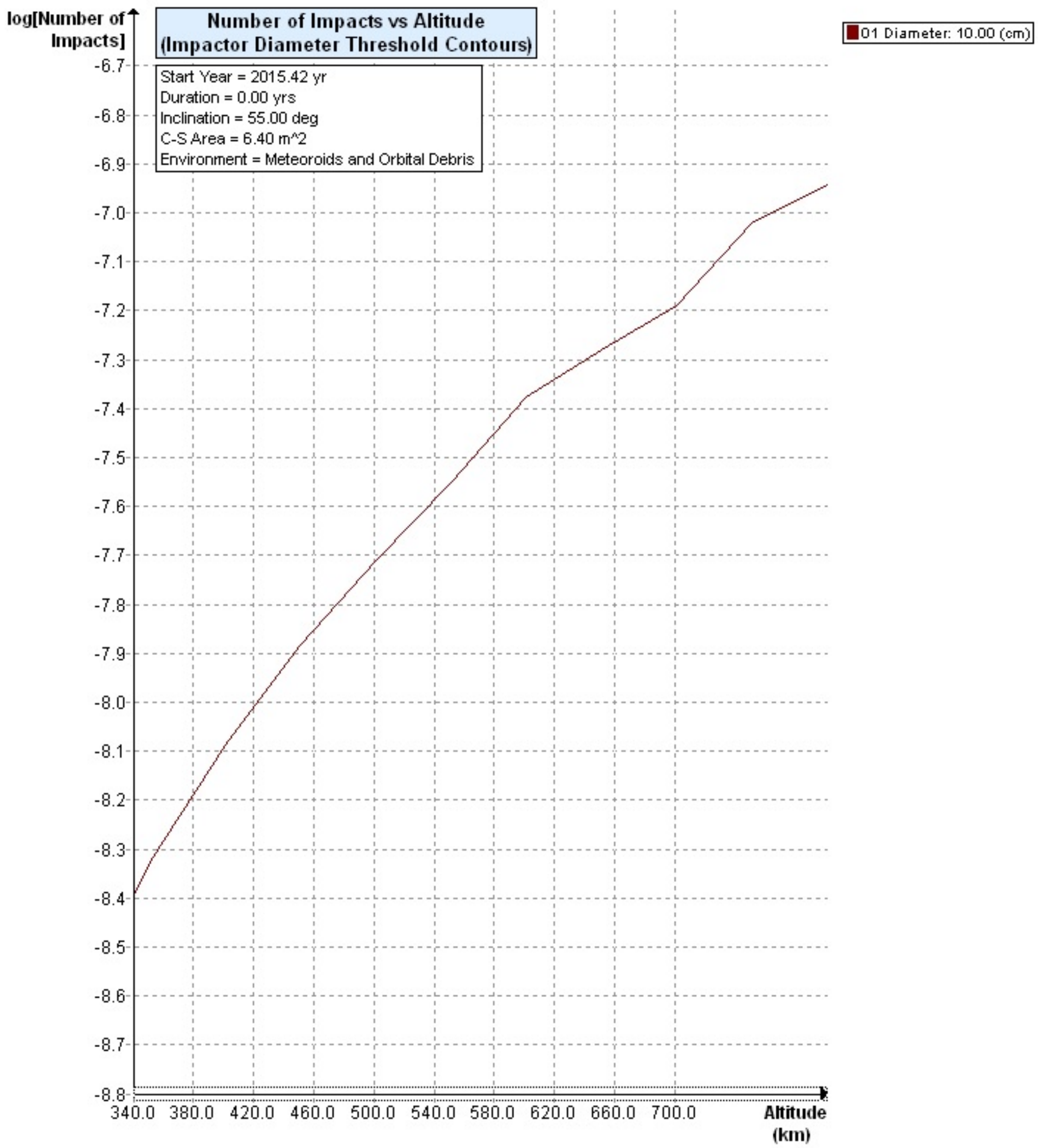


Figure 3: Risk of Orbit Collision vs. Altitude (LightSail-A)

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 a LightSail-A collision with debris and meteoroids greater than 10 cm in diameter was calculated with DAS to be 2x10^-5 in a worst case situation. 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.

Section 6: Assessment of Spacecraft Postmission Disposal Plans and Procedures

LightSail-A 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 LightSail-A in its stowed configuration as the worst case. The area-to-mass is calculated for is 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 2: Area to Mass

$$\frac{0.0391\ m^2}{4.85\ kg} = 0.0081\frac{m^2}{kg}$$

A stowed LightSail-A has the smallest Area-to-Mass ratio and as a result will have the longest orbital lifetime. 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: 342 km maximum perigee 700 km maximum apogee altitudes with an inclination of 55 degrees at deployment in the year 2015. An area to mass ratio of 0.0081 m^2/kg for the LightSail-A CubeSat was imputed. DAS 2.0.2 yields a 5.3 years orbit lifetime for LightSail-A in its stowed state.

This meets requirement 4.6-1. For the complete list of CubeSat orbital lifetimes reference.

Assessment results show compliance.

Section 7: Assessment of Spacecraft Reentry Hazards

A detailed assessment of the components to be flown on ELaNa-11 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 5.

Table 5: ELaNa-11 Stainless Steel DAS Analysis

CubeSat	ELaNa-11 Stainless Steel Components	Mass (g)	Diameter/ Width (cm)	Length (cm)	Height (cm)		Demise Alt (km)	KE (J)
LightSail-A	Antenna	2.3	0.6	17.3	0.025		0	0
LightSail-A	Panel Hinge Shaft	3	0.24	4.8	-		77.8	0
LightSail-A	Deployable Panel Spring	0.4	0.5	0.56	-		77.1	0
LightSail-A	Battery Mount Shaft	1.7	0.24	5.6	-		77.1	0
LightSail-A	Board Stack Standoff	1.1	0.6	0.6	-		76.3	0
LightSail-A	#2-56 SHBS 1"	0.6	0.22	2.5	-		77.9	0
LightSail-A	#4-40 x 3/8" SHCS	0.5	0.28	0.95	-		77.9	0
LightSail-A	0.0012	1.2	0.28	0.3	-		77.5	0
LightSail-A	#2-56 SHBS 3/4"	0.5	0.22	1.9	-		77.9	0
LightSail-A	#2-56 SHBS 1"	0.5	0.22	2.5	-		77.9	0
LightSail-A	#2-56 SHBS 3/16"	0.2	0.22	0.48	-		77.9	0
LightSail-A	#0-80 x 0.125" SHCS	0.1	0.15	0.3	-		77.9	0

The majority of stainless steel components demise upon reentry. The component that DAS conservatively identifies as reaching the ground have 0 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 5: ELaNa-11 Stainless Steel DAS Analysis, and the full component lists in the Appendix all CubeSats launching under the ELaNa-11 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-11 CubeSats will not be deploying any tethers.

ELaNa-11 CubeSats satisfy Section 8's requirement 4.8-1.

Section 9-14

ODAR sections 9 through 14 for the launch vehicle are addressed in primary ULTRASAT ODAR, 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
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SA-D2/Mr. Hidalgo
SA-D2/Mr. Hibshman
AIS-22/Ms. Nighswonger

Appendix Index:

Appendix A. ELaNa-11 Component List by CubeSat: LightSail-A

Appendix A. ELaNa-11 Component List by CubeSat: **LightSail-A**

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
LightSail-A		1		3U CubeSat							
CubeSat Structure: Main Side	External - Major	2	Aluminum 6061-T6	Box	142	100	340.5	17	yes	284	Demise
CubeSat Structure: Plate	External - Major	2	Aluminum 6061-T6	Plate	28	8	9.5	0.3	yes	-	Demises
Antenna	External - Major	1	Blue Clock Spring Steel (SAE 1095;ASTM A684)	Strip	2.3	6	173	0.25	no	1650	Negligible Risk: KE ~ 0 J. See Table 4
Solar Panels	External - Major	4	FR4	Rectangular	172	78	320	1.5	yes	-	Demise
Solar Sail	External - Major	4	Aluminized Mylar	Triangle	126	5570	2x 3930		yes	-	Demise
Solar Sail TRAC Boom: AFRL	External - Major	4	Elgiloy (40% Co; 20% Cr; 15% Ni alloy) 85% Cold Reduction	2 strips	227	20	4000	20	yes	-	Demise
Camera: Aerospace Corp.	External - Major	2	Aluminum housing 6061-T6	Rectangular	30.2	69	44	30	yes	-	Demise
Sep Switches	External - Minor	2	PPS/PBT Polymer Housing	Box		2.7	10.5	8.2	yes	-	Demise
Sun Sensor	External - Minor	2	FR4	Board	2.2	7	23	1.6	yes	-	Demise
Panel Hinge Shaft	External - Minor	4	316 Stainless Steel	Rod	3	2.4	48		no	1399	Demise; see Table 4
Hinge Plate Left	External - Minor	8	Aluminum 6061-T6	Plate	1	10	8	5.6	yes	-	Demise
Hinge Plate Right	External - Minor	8	Aluminum 6061-T6	Plate	1	10	8	5.6	yes	-	Demise
Deployable Panel Bushing	External - Minor	8	Delrin AF	Bushing	0.04	4	1.4		yes	-	Demise
Deployable Panel Stop	External - Minor	4	Aluminum 6061-T6	Triangle	1.8	25	25	4	yes	-	Demise
Deployable Panel Spring	External - Minor	8	302 Stainless Steel	Spring	0.4	5	5.6		no	1538	Demise; see Table 4
Solar Cells: Spectro Lab	External - Minor	52	Germanium	Flat panel	3.8	69	40	0.2	yes	-	Demise

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
Batteries	Internal - Major	8 cells	Lithium Polymer	Rectangular	15	49	30	6	yes	-	Demise
Torque Rod	Internal - Major	3	Al housing/Cu coils/Adhesive	Rod	170	22	94		yes	-	Demise
Payload Board: Stellar	Internal - Major	1	FR4	Board	39.6	83	83	5	yes	-	Demise
Motherboard Assembly (includes transiever): Tyvak	Internal - Major	1	FR4	Board	75.6	83	83	5	yes	-	Demise
Battery Board: Cal Poly	Internal - Major	1	FR4	Board	12.2	43	50	4	yes	-	Demise
Sail Housing	Internal - Major	1	Aluminum 6061-T6	Box	238	100	100	122.5	yes	-	Demise
Boom Housing	Internal - Major	1	Aluminum 6061-T6	Box	387	103	103	46	yes	-	Demise
Gyro: Analog Devices	Internal - Minor	3	component	Box	25	36	44	14	yes	-	Demise
Battery Retainer	Internal - Minor	4	Delrin	Box	4	33	60	10	yes	-	Demise
Battery Mount Shaft	Internal - Minor	3	18-8 Stainless Steel	Rod	1.7	2.4	56		no	1450	Demise; see Table 4
Torque Rod Mounts	Internal - Minor	6	Aluminum 6061-T6	Plate	3.2	22	13	2	yes	-	Demise
Momemtum Wheel Mass Model	Internal - Minor	1	6061-T6	Circular Box	230.6	75	68	35	yes	-	Demise
Board Stack Standoff	Internal - Minor	4	18-8 Stainless Steel	Ring	1.1	6	6	-	no	1450	Demise; see Table 4
Corner Cube	Internal - Minor	4	N-BK7 Glass	Cube	1.7	10	10	10	yes	-	Demise
#2-56 SHBS 1"	Internal - Minor	4	18-8 Stainless Steel	screw	0.6	2.2	25	-	no	1450	Demise; see Table 4
#4-40 x 3/8" SHCS	Internal - Minor	12	316 Stainless Steel	screw	0.5	2.8	9.5	-	no	1399	Demise; see Table 4
#4-40 Shoulder Screw	Internal - Minor	8	18-8 Stainless Steel	screw	1.2	2.8	3	-	no	1450	Demise; see Table 4
#2-56 SHBS 3/4"	Internal - Minor	4	18-8 Stainless Steel	screw	0.5	2.2	19	-	no	1450	Demise; see Table 4
#2-56 SHBS 1"	Internal - Minor	8	18-8 Stainless Steel	screw	0.5	2.2	25	-	no	1450	Demise; see Table 4
#2-56 SHBS 3/16"	Internal - Minor	34	18-8 Stainless Steel	screw	0.2	2.2	4.8	-	no	1450	Demise; see Table 4

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
Main Harness with connectors	Internal - Minor	1	Copper Wire/Polyamide/Black LCP Insulation	wire	22	-	-	-	yes	-	Demise
Panel Harness	Internal - Minor	2	Copper/Kapton	wire	0.6	-	-	-	yes	-	Demise
Flex Cables	Internal - Minor	4	Kapton/Copper	flat wire	0.2	-	-	-	yes	-	Demise
RF Cable	Internal - Minor	1	Phosphor Bronze/Silver/Brass	wire	1.7	-	-	-	yes	-	Demise