ELVL-2016-0044593 Rev B
June 25, 2018

Orbital Debris Assessment for The CubeSats on the ICESat-2 /ELaNa-18 Mission per NASA-STD 8719.14A

Signature Page

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Rex Engelhardt, Mission Manager, NASA KSC VA-C

RECORD OF REVISIONS		
REV	**DESCRIPTION**	**DATE**
0	Basic Issue	February 2017
A	Deletion of CHIEFSat. Addition of ELFIN-Star and SURFSat	April 2018
B	Updated SURFSat mass properties and ELFIN CubeSat nomenclature	June 2018

National Aeronautics and
Space Administration

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

ELVL-2016-0044593

Reply to Attn of: VA-H1

June 25, 18

TO: Rex Engelhardt, LSP Mission Manager, NASA/KSC/VA-C

FROM: Yusef Johsnon, a.i. solutions/KSC/AIS2

SUBJECT: Orbital Debris Assessment Report (ODAR) for the ICESat-2/ELaNa-18 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. *Preliminary Mission Analysis for the Delta II 7420/ICESat-2 Spacecraft Mission – CDRL C4-1, PGAA#2*, ULA-TP-16-163, Sept 2016
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-18 auxiliary mission launching in conjunction with the ICESat2 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 primary mission and are not presented here.

The following table summarizes the compliance status of the ELaNa-18 auxiliary payload mission flown on IceSat-2. The four CubeSats comprising the ELaNa-18 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 4.4 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-18 mission

Section 1: Program Management and Mission Overview

The ElaNa-18 mission is sponsored by the Human Exploration and 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:

DAVE: Dr. Jordi Puig-Suari & Dr. John Bellardo, Principal Investigators; Justin Foley, Project Manager

ELFIN-A & ELFIN-B: Lydia Bingley, Principal Investigator; Anais Zarifian, Systems Engineer

SURFSat: Adrienne Dove, Principal Investigator, Joshua Cowell & Dawn Trout, Co-Investigators

Program Milestone Schedule	
Task	Date
CubeSat Selection	11/16/2017
MRR	6/25/2018
CubeSat Integration into P-PODs	7/30/2018
CubeSat Delivery to VAFB	7/30/2018
Launch	9/12/2018

Figure 1: Program Milestone Schedule

The ElaNa-18 mission will be launched as an auxiliary payload on the NASA ICESat-2 mission on a Delta II 7420-10 launch vehicle from VAFB, CA. The ElaNa-18 compliment, will deploy 4 pico-satellites (or CubeSats). The CubeSat slotted position is identified in Table 2: ElaNa-18 CubeSats. The ElaNa-18 manifest includes: Dave, ELFIN-A, ELFIN-B, and SURFSat. The current launch date is in September 12, 2017. The 4 CubeSats are to be ejected from PPOD deployers mounted on the Delta II second stage, placing the CubeSats in an orbit approximately 450 X 473 km at inclination of 93.0 deg (ref. (h)).

The CubeSat dimensions range from the 1U configuration 10 cm x 10cm x 10 cm, to a 3U configuration of 10cm x 10 cm x 34 cm with masses from about 3.2 kg to 3.7 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 4 CubeSats flying on the ElaNa-18 Mission. Table 2: ElaNa-18 CubeSats outlines their generic attributes.

Table 2: ElaNa-18 CubeSats

CubeSat Names	P-POD #	CubeSat size	CubeSat Masses (kg)
DAVE	3	1U (10cm x 10cm x 11cm)	1.4
ELFIN-A	1	3U (10cm X 10cm X 34cm)	3.4
ELFIN-B	2	3U (10cm X 10cm X 34cm)	3.4
SURFSat	3	2U (10cm x 10cm x 22cm)	2.0

The following subsections contain descriptions of these 4 CubeSats.

Dave – California Polytechnic University – 1U

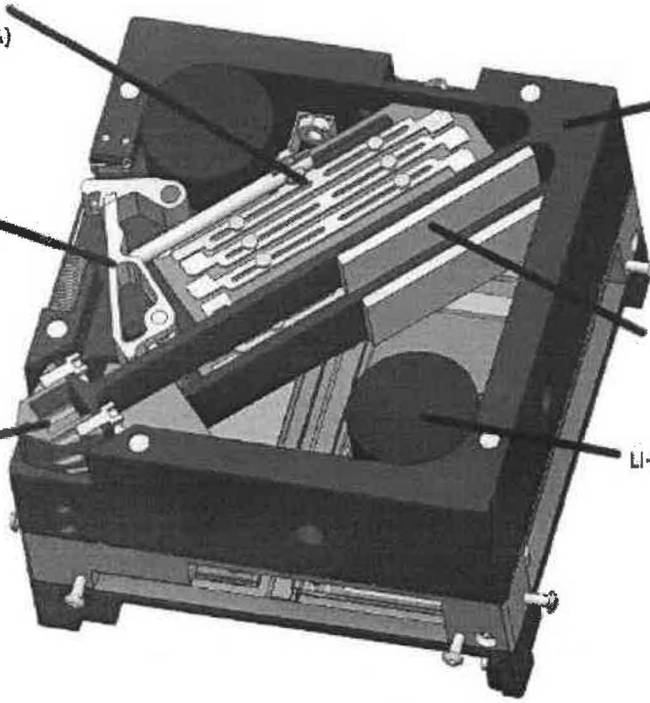

Figure 2: DAVE Assembled View

Overview: The Damping and Vibration Experiment (DAVE) CubeSat implements a payload to evaluate a mechanical damping technology in microgravity. This technology, called particle damping, exploits the dynamics of multiple constrained particles to dissipate vibration energy. Terrestrial applications demonstrate particle damping performance to be largely unaffected by extreme environments yet simple and cheap to implement. This feature set makes particle damping an attractive technology for applications in spacecraft, where dampers are needed to steady sensitive instrumentation and inhibit destructive structural resonant modes.
In orbit, DAVE provides a low cost and low risk platform to characterize unknown particle damper microgravity behavior and provide flight heritage for particle damper technology. The completion of these objectives overcomes barriers currently inhibiting the employment of particle dampers in space.

DAVE is equipped with one OmniVision imager. The primary purpose of the imager is verifying the rotation rates of the spacecraft prior to performing experiments. The secondary mission is acquiring Earth imagery to support public outreach activities.

CONOPS: After deployment from the P-POD, the satellite will power on. Approximately 15 minutes later, antenna deployment will occur. 115 minutes after antenna deployment, the beacon will be activated and the satellite will be available to acquire with the ground station. A full parameter sweep vibration experiment will begin automatically within a few hours of launch. Results will be downloaded over subsequent passes. Additional experiments can be commanded from the ground as necessary to improve confidence in the results.

Materials: The structure is made entirely of 6061-T6 Aluminum. The antenna is made of NiTi and Delrin. The ceramic piezo electric beam actuators are lead zirconate titanate. The tips of the booms contain tungsten particles. The satellite contains mostly standard commercial off the shelf materials, electrical components, PCBs, and solar cells.

Hazards: There are no pressure vessels, hazardous materials, or exotic materials. The cavities containing the tungsten particles are not freely vented.

Batteries: There are 2x UL listed 3.7V 2600mAh Lithium-Ion 18650 batteries connected in parallel. The UL listing number is MH48285. There is battery protection circuitry and over-charge protection.

ELFIN-A/ELFIN-B – UCLA – 3U+

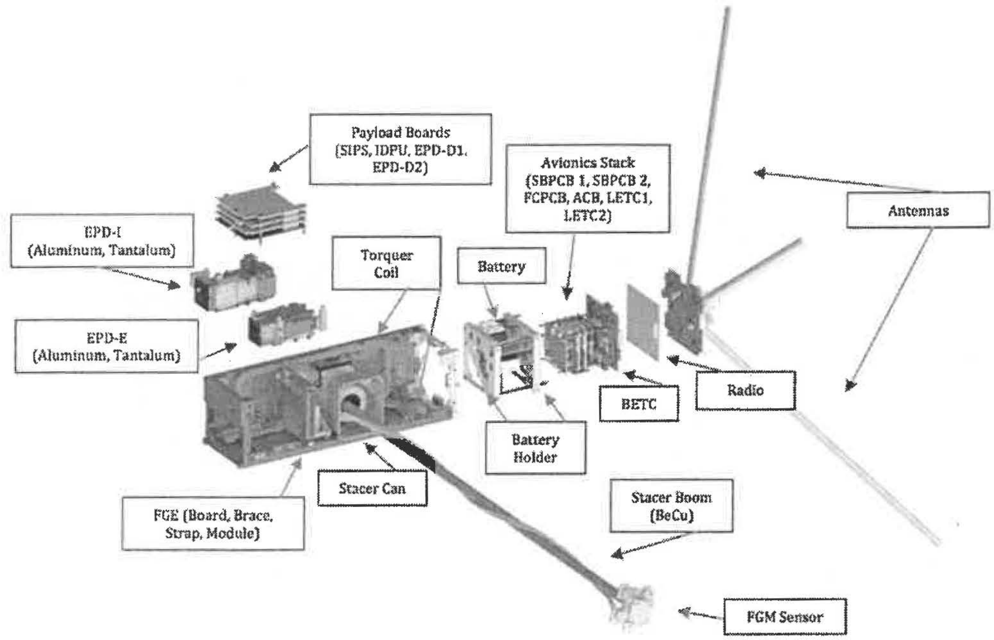

Figure 3: ELFIN Expanded View

Overview: The Electron Losses and Fields Investigation (ELFIN) Mission, is a space weather CubeSat that will investigate the loss of relativistic particles from the radiation belts into the Earth's atmosphere. ELFIN will accomplish this using two primary payload instruments; a fluxgate magnetometer and an energetic particle detector.

CONOPS: Upon deployment from the PPOD, each ELFIN CubeSat will power up and initiate a 45 minute timer counting down for antenna deployment. If tip off rates from the PPOD are large, ELFIN will execute an automatic detumble sequence in order to get the spacecraft in a stable attitude configuration. At 45 minutes, the UHF/VHF antennas will deploy, and the spacecraft will begin beaconing. After communication with the ground is established, spacecraft and instrument commissioning will begin. At a minimum of 2 weeks after deployment, the stacer boom will be commanded to deploy, the spacecraft will be spun up to ~20 rmp, and nominal operations will begin. Science will resume for a minimum of 3 months (nominally 6 months).

Materials: ELFIN's structure is primarily composed of Aluminum 6061-T6, with some peek components as additional structural components. Most materials are standard commercial off the shelf, as well as standard electrical components, printed circuit boards, and solar cells. The Energetic Particle Detector is built with a combination of Aluminum and Tantalum parts. All Tantalum parts are internal components, and are relatively small.

Hazards: There are no pressure vessels or hazardous materials on this satellite.

Batteries: The power system uses 4 Molicel ICR18650J Lithium-ion batteries that are screened by the Aerospace Corporation before delivery to ELFIN. The UL listing number is BBCV2.MH27672.

SURFSat – University of Central Florida – 2U

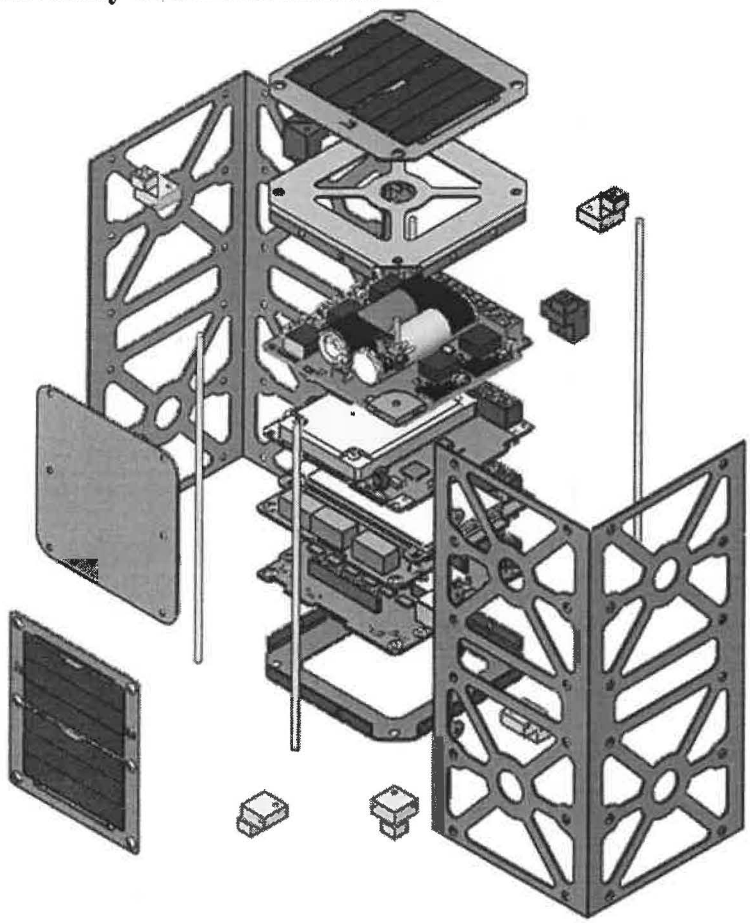

Figure 4: SURFSat Expanded View

Overview: The space radiation environment in Earth's atmosphere is filled with hot and low-density plasmas that can cause charge to build up on spacecraft surfaces, resulting in high differential voltages and subsequent electrostatic discharges. These discharges can damage avionics and/or scientific instruments on spacecraft. SURFSat will take in-situ measurements of the ground current waveforms from chosen common spacecraft dielectric material samples, measure the spacecraft and material potentials, and will use a Langmuir probe system to measure the ambient plasma environment. The sample materials will span a range of resistivities that will be chosen both for relevance and in order to maximize scientific return. Comparison of on-orbit ESD measurements with completed and ongoing plasma chamber charging experiments will be used to validate current plasma charging test methods. These experiments will be used to develop design criteria, and help avoid potentially disastrous discharging on spacecraft.

CONOPS: Upon deployment from the PPOD, SURFSat will power up and initially enter a charging phase. It will then deploy two Langmuir Probe booms and begin collecting data. Data collection consists of voltage and current measurements from the dielectric surfaces on the experiment, and measurements from the dielectric probe. Langmuir probe and surface voltage measurements will be stored continuously during operation, but high data rate current data is recorded in a circular buffer, and only stored in long-term memory if triggered by an an on-orbit ESD event. Data is stored onboard the computer until downlinked.

Materials: The primary CubeSat structure is made of 6061 Aluminum. In addition to the solar cells on the outside of the spacecraft, the sample materials are made of aluminum substrates with aerospace industry standard paints and coatings. Other than that, the CubeSat contains all standard commercial off the shelf (COTS) materials, electrical components, and PCBs.

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

Batteries: We use standard PCB material and electronics components. The solar cells are 23% Spectrolab CICs. The electrical power storage system consists of common Lithium Iron Phosphate (LFP) batteries with over-charge/current protection circuitry (UN38.3 passed).

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-18 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-18 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 maximum CubeSat lifetime of 4.4 years maximum the ElaNa-18 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 4 CubeSats is that of both of the ELFIN CubeSats with deployable extended (2x long antennas, 2x short antennas, Tuna Can, Stacer Boom and Sensor.):

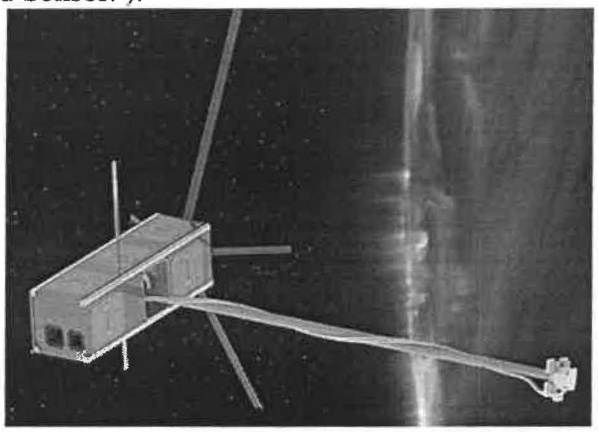

Figure 5: ELFIN Deployed Configuration

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

Equation 1: Mean Cross Sectional Area for Convex Objects

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

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 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 component dimensions used in these calculations

The ELFIN Project CubeSats (3.26 kg) orbit at deployment is 476 km apogee altitude by 450 km perigee altitude, with an inclination of 93 degrees. With an area to mass ratio of 0.019 m^2/kg, DAS yields 4.4 years for orbit lifetime for its deployed state, which in turn is used to obtain the collision probability. Even with the variation in CubeSat design and orbital lifetime ElaNa-18 CubeSats see an average of 0.00000 probability of collision. All CubeSats on ElaNa-18 were calculated to have a probability of collision of 0.00000. 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	Dave	ELFIN-A/ELFIN-B	SURFSat
	Mass (kg)	1.33	3.26	2.0
Stowed	Mean C/S Area (m^2)	0.016	0.036	.0278
Stowed	Area-to Mass (m^2/kg)	0.012	0.011	0.014
Stowed	Orbital Lifetime (yrs)	**3.9**	**4.4**	**3.8**
Stowed	Probability of collision (10^X)	**0.00000**	**0.00000**	**0.00000**
Deployed	Mean C/S Area (m^2)	[redacted]	0.062	[redacted]
Deployed	Area-to Mass (m^2/kg)	[redacted]	0.019	[redacted]
Deployed	Orbital Lifetime (yrs)	[redacted]	**3.9**	[redacted]
Deployed	Probability of collision (10^X)	[redacted]	**0.00000**	[redacted]

Solar Flux Table Dated
8/4/2017

The probability of any ElaNa-18 spacecraft collision with debris and meteoroids greater than 10 cm in diameter and capable of preventing post-mission disposal is less than 0.00000, 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-18 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-18 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 SurfSat in its stowed configuration as the worst case. The area-to-mass is calculated for is as follows:

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

Equation 3: Area to Mass

$$\frac{0.036\, m^2}{3.26 kg} = 0.011 \frac{m^2}{kg}$$

ELFIN and ELFIN-Star have 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: 476 km maximum apogee 450 km maximum perigee altitudes with an inclination of 93 degrees at deployment no earlier than November 2018 An area to mass ratio of 0.011 m^2/kg for the ELFIN-A/ELFIN-B CubeSats was imputed. DAS 2.1.1 yields a 4.4 years orbit lifetime for ELFIN-A or ELFIN-B 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-18 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 and Table 4.

Table 4: ELaNa-18 High Melting Temperature Material Analysis

CubeSat	High Temp Component	Material	Mass (g)	Demise Alt (km)	KE (J)
DAVE	Antenna Wire	Nickel Titanium	2.5	0	0
DAVE	Tungsten Crystalline Powder	Tungsten	20	0	0
ELFIN	Back Wall	Tantalum	19.35	0	13
ELFIN	Side Wall (outer)	Tantalum	11.91	0	10
ELFIN	Side Wall (top&bot)	Tantalum	16	0	13
ELFIN	Side Wall (inner)	Tantalum	4.59	0	4
ELFIN	E Front	Tantalum	16.73	0	9
ELFIN	Auxiliary Shield T 1	Tantalum	7.93	0	6
ELFIN	Auxiliary Shield G 1	Tantalum	8.98	0	6
ELFIN	Auxiliary Shield T 2	Tantalum	6.44	0	4
ELFIN	Auxiliary Shield G 2	Tantalum	7.47	0	4

* S-Band Radio assembly was modeled as all Stainless Steel, which is conservative. It is likely that less than ½ of the mass is actually stainless steel.

CubeSat	High Temp Component	Material	Mass (g)	Demise Alt (km)	KE (J)
ELFIN	Auxiliary Shield G 3	Tantalum	6.4	0	3
ELFIN	Auxiliary Shield T 4	Tantalum	5.04	0	2
ELFIN	Auxiliary Shield G 4	Tantalum	5.26	0	2
ELFIN	Back Wall	Tantalum	19.35	0	13
ELFIN	Side Wall	Tantalum	6.03	0	5
ELFIN	Side Wall (Outer)	Tantalum	4.21	0	3
ELFIN	Side Wall (Inner)	Tantalum	1.7	0	1
ELFIN	Mag Stage Front	Tantalum	10.98	0	5
ELFIN	Cone Wall	Tantalum	7.21	0	2
ELFIN	Auxiliary Shield M	Tantalum	0.57	0	0
ELFIN	Payload Rods	#4 Titanium Rod	1	0	0
ELFIN	Auxiliary Shield T 3	Tantalum	5.69	0	3

All components have less than 15J of energy upon reentry. As a result probability of Human Casualty is not calculated, resulting in automatic compliance with the 1:10,000 probability of Human Casualty Requirement 4.7-1.

All CubeSats launching under the ElaNa-18 mission are 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-18 CubeSats will not be deploying any tethers.

ElaNa-18 CubeSats satisfy Section 8's requirement 4.8-1.

Section 9-14

ODAR sections 9 through 14 for the launch vehicle are not covered here.

If you have any questions, please contact the undersigned at 321-867-2098.

/original signed by/

Yusef Johnson
Flight Design Analyst
a.i. solutions/KSC/AIS2

cc: VA-H/Mr. Carney
VA-H1/Mr. Beaver
VA-H1/Mr. Haddox
VA-C2/Mr. Hall
SA-D2/Mr. Frattin
SA-D2/Mr. Hale
SA-D2/Mr. Henry
Analex-3/Mr. Davis
Analex-22/Ms. Ramos

Appendix Index:

Appendix A. ELaNa-18 Component List by CubeSat: DAVE

CUBESAT	Name	Qty	Material	Body Type	Mass (g) (total)	Diameter/ Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp	Survivability
DAVE	DAVE	1	Various	Box	1.4	100	100	113.5	No	-	-
DAVE	CubeSat Structure	1	Aluminum 6061	Box	535	100	100	113.5	No	-	Demise
DAVE	Antenna Route	1	Delrin	Square	7	65	65	3.5	No	-	Demise
DAVE	Antenna Wire	2	Nickel Titanium (NiTi)	Rectangular	2.5	0.3	160	0.5	Yes	1400	Survives with 0J energy. See Table 5
DAVE	Solar Cells	10	Eglass	Rectangular	2.2512	0.5	68	40	No	-	Demise
DAVE	Side Panels	5	FR4 Multilayer PCB	Rectangular	35	1.5	83	72	No	-	Demise
DAVE	Z-Panels	1	FR4 Multilayer PCB	Square	45	1.5	100	100	No	-	Demise
DAVE	Cavity Caps	3	316 Stainless Steel	Box	10.5	20	13	13	Yes	1400	Demise
DAVE	Ceramic Piezoelectric Actuators	3	Lead Zirconate Titanate	Box	3.5	2.54	44.45	12.7	No	-	Demise
DAVE	Tungsten Crystalline Powder*	200	Tungsten	Powder	20	2.15	-	-	Yes	3422	Survies with 0J energy. See Table 5
DAVE	SMA Actuators Boards	4	Nickel Titanium (NiTi)	Wire	0.5	0.05	100	N/A	Yes	1400	Demise
DAVE	SMA Actuators wire	4	FR4 Multilayer PCB	Rectangular	22	1.524	68.707	24.257	No	-	Demise
DAVE	Torque Shaft	1	Aluminum 6061	Cylindrical	3	4		62	No	-	Demise
DAVE	Locking springs	3	302 Stainless	Cylindrical	3	6.9	10	-	Yes	1500	Demise
DAVE	Sep/Actuating Switches	5	Plastic (PBT)	Rectangular	2	6	8	7	No	-	Demise
DAVE	Batteries	2	Lithium Ion	Cylindrical	90.7	26.3	65.8	-	No	-	Demise
DAVE	Payload Board	2	FR4 Multilayer PCB	Board	33	1.5	83	83	No	-	Demise
DAVE	Sensor Board	3	FR4 Multilayer PCB	Board	5	1.5	32	32	No	-	Demise
DAVE	Comm Board	1	FR4 Multilayer PCB	Board	12	1.5	83	36	No	-	Demise
DAVE	Breakout Board	1	FR4 Multilayer PCB	Board	12	1.5	83	36	No	-	Demise
DAVE	C&DH Board	1	FR4 Multilayer PCB	Board	30	1.5	83	83	No	-	Demise
DAVE	Fasteners	1	18-8 Stainless	Screw	35	2.2	Various	-	Yes	1500	Demise
DAVE	Staking Compound	1	3M Scotch Weld 2216	Rectangular	15	-	-	-	No	-	Demise
DAVE	Heat Shrink	1	RNF-100 Polyolefin Heat Shrink	Tube	0	-	-	-	No	-	Demise
DAVE	Kapton Tape	1	Kapton Tape	Tape	0	Various	Various	0.05	No	-	Demise

Appendix B. ElaNa-18 Component List by CubeSat: ELFIN-A/ELFIN-B

CUBESAT	Name	Qty	Material	Body Type	Mass (g) (total)	Diameter/ Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp	Survivability
ELFIN	ELFIN	1		Box						-	
ELFIN	Chassis Rail (+x,+y)	1	Aluminum 6061-T6	Bar	48.94	7	18.8	322.38	No	-	Demise
ELFIN	Chassis Rail (-x,+y)	1	Aluminum 6061-T6	Bar	50.79	7	18.74	322.38	No	-	Demise
ELFIN	Chassis Rail (+x,-y)	1	Aluminum 6061-T6	Bar	51.06	7	18.8	322.38	No	-	Demise
ELFIN	Chassis Rail (-x,-y)	1	Aluminum 6061-T6	Bar	53.52	7	18.8	322.38	No	-	Demise
ELFIN	Top Hat (-Z)	1	Aluminum 6061-T6	Block	55.79	100	100	24.3	No	-	Demise
ELFIN	Top Hat (+Z)	1	Aluminum 6061-T6	Block	100.97	100	100	24.3	No	-	Demise
ELFIN	Tuna Can (+ Unit)	1	Windform LX2.0	Cylinder	48	61.01	-	30	No	-	Demise
ELFIN	Stacer Boom	1	Wrought Copper	Rod	-	29	750	-	Yes	1085	Demise
ELFIN	Stacer Tip Piece	2	Peek	Block	4.6	5	20.08	49.82	No	-	Demise
ELFIN	Mag Sensor	1	6061-T6 A, Copper, ferrite, NdFeB	Box	-	-	-	-	No	-	Demise
ELFIN	Mag Cable	1	6061-T6 A, Copper	Cable	-	-	-	-	No	-	Demise
ELFIN	Antenna (long)	2	BeCu / Fiber Glass	Thin sheet	6.9	13.8	609.6	-	No	-	Demise
ELFIN	Antenna (short)	2	BeCu / Fiber Glass	Thin sheet	2.91	13.8	228.6	-	No	-	Demise
ELFIN	(+y - long) Solar Panel	1	FR4	PCB	48	1.65	82	146.33	No	-	Demise
ELFIN	(+y - short) Solar Panel	1	FR4	PCB	38	1.65	82	112.95	No	-	Demise
ELFIN	(+y) Solar Cell	4	GaInP2/GaAs/Ge	Sheet	2.54	39.3	69.5	-	No	-	Demise
ELFIN	(-y) Solar Panel	1	FR4	PCB	111	1.65	82	329.29	No	-	Demise
ELFIN	(-y) Solar Cell	6	GaInP2/GaAs/Ge	Sheet	2.54	39.3	69.5	-	No	-	Demise
ELFIN	(+x) Solar Panel	1	FR4	PCB	112	1.65	82	329.29	No	-	Demise
ELFIN	(+x) Solar Cell	6	GaInP2/GaAs/Ge	Sheet	2.54	39.3	69.5	-	No	-	Demise
ELFIN	(-x) Solar Panel	1	FR4	PCB	111	1.65	82	329.29	No	-	Demise
ELFIN	(-x) Solar Cell	4	GaInP2/GaAs/Ge	Sheet	2.54	39.3	69.5	-	No	-	Demise
ELFIN	(+z) Solar Panel	1	FR4	PCB	19	1.65	98.98	61.9	No	-	Demise
ELFIN	(-z) Solar Panel	1	FR4	PCB	32	1.65	97.97	97.97	No	-	Demise
ELFIN	Fasteners	48	Brass	Rod	0.25	-	-	-	No	-	Demise
ELFIN	Shield Insert	1	Aluminum 6061-T6	Block	6.29	23.3172	19.8628	12.5222	No	-	Demise
ELFIN	Aluminum Shield	1	Aluminum 6061-T6	Block	71.78	39.0144	33.8328	39.0144	No	-	Demise
ELFIN	Back Wall	1	Tantalum	Block	19.35	20.94992	4.59994	20.94992	Yes	2980	Survives - See Table 4
ELFIN	Side Wall (outer)	1	Tantalum	Block	11.91	16.74876	2.99974	14.65072	Yes	2980	Survives - See Table 4
ELFIN	Side Wall (top&bot)	2	Tantalum	Block	16	16.74876	2.99974	20.94992	Yes	2980	Survives - See Table 4
ELFIN	Side Wall (inner)	2	Tantalum	Block	4.59	16.74876	5.4991	2.99974	Yes	2980	Survives - See Table 4
ELFIN	Spacer	1	Aluminum 6061-T6	Block	0.4	12.90066	0.89408	12.90066	No	-	Demise
ELFIN	Insulator Side	1	PEEK	Block	0.19	17.74952	4.4704	6.55066	No	-	Demise
ELFIN	Wave Spring Washer	1	Beryllium Copper UNS C17200	Block	0.052	4.18846	0.127	-	No	-	Demise

CUBESAT	Name	Qty	Material	Body Type	Mass (g) (total)	Diameter/ Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp	Survivability
ELFIN	Insulator Back	1	PEEK	Block	0.19	12.90066	0.84328	12.90066	No	-	Demise
ELFIN	Spacer MSD	1	PEEK	Block	0.138	12.99972	1.80086	12.99972	No	-	Demise
ELFIN	Foil Frame Back	1	Aluminum 6061-T6	Block	0.19	14.69898	0.73406	14.69898	No	-	Demise
ELFIN	Lexan Foil	1	Aluminum 6061-T6	Sheet	0.01	14.50086	-	14.50086	No	-	Demise
ELFIN	Foil Frame Front	1	Aluminum 6061-T6	Block	0.11	14.69898	0.5588	14.69898	No	-	Demise
ELFIN	E Front	1	Tantalum	Block	16.73	20.94992	5.74802	20.94992	Yes	2980	Survives - See Table 4
ELFIN	E Aperture 1	1	Phosphor Bronze	Block	4.536	21.7932	1.61036	21.7932	No	-	Demise
ELFIN	Aperture Frame	1	Aluminum 6061-T6	Block	69.08	39.0144	48.895	39.0144	No	-	Demise
ELFIN	Auxiliary Shield T 1	2	Tantalum	Block	7.93	18.71726	2.49936	10.28954	Yes	2980	Survives - See Table 4
ELFIN	Auxiliary Shield G 1	2	Tantalum	Block	8.98	23.3553	3.18008	10.28954	Yes	2980	Survives - See Table 4
ELFIN	E Aperture 2	1	Phosphor Bronze	Block	5.8	25.8064	1.61036	25.8064	No	-	Demise
ELFIN	Auxiliary Shield T 2	2	Tantalum	Block	6.44	21.0058	1.80086	10.28954	Yes	2980	Survives - See Table 4
ELFIN	Auxiliary Shield G 2	2	Tantalum	Block	7.47	25.6032	2.99974	10.28954	Yes	2980	Survives - See Table 4
ELFIN	E Aperture 3	1	Phosphor Bronze	Block	5.06	26.1112	1.61036	26.1112	No	-	Demise
ELFIN	Auxiliary Shield T 3	2	Tantalum	Block	5.69	21.51126	1.45034	11.03884	Yes	2980	Survives - See Table 4
ELFIN	Auxiliary Shield G 3	2	Tantalum	Block	6.4	25.8572	2.90068	11.03884	Yes	2980	Survives - See Table 4
ELFIN	E Aperture 4	1	Phosphor Bronze	Block	4.07	21.7932	1.61036	21.7932	No	-	Demise
ELFIN	Auxiliary Shield T 4	2	Tantalum	Block	5.04	22.96668	1.19888	11.03884	Yes	2980	Survives - See Table 4
ELFIN	Auxiliary Shield G 4	2	Tantalum	Block	5.26	26.28646	2.3495	11.03884	Yes	2980	Survives - See Table 4
ELFIN	E Aperture 5	1	Phosphor Bronze	Block	7.46	32.766	1.5748	32.766	No	-	Demise
ELFIN	Sensor E	1	Polyimide/G-10/Silicon Dioxide/PEEK/Epoxy	Block	3.63	12.94892	9.70788	12.94892	No	-	Demise
ELFIN	Preamp Cover Top	1	Aluminum 6061-T6	Block	22.17	56.90	19.02	43.33	No	-	Demise
ELFIN	Preamp Cover Base	1	Aluminum 6061-T6	Block	15.15	56.90	7.62	43.33	No	-	Demise
ELFIN	Preamp Spacer	4	Aluminum 6061-T6	Cylinder	0.09	3.81	4.57	-	No	-	Demise
ELFIN	Aluminum Shell I	1	Aluminum 6061-T6	Block	44.39	45.42	19.46	39.01	No	-	Demise
ELFIN	Mag Stage Frame	1	Aluminum 6061-T6	Block	48.55	39.01	25.27	39.01	No	-	Demise
ELFIN	Back Wall	1	Tantalum	Block	19.35	20.95	4.60	20.95	Yes	2980	Survives - See Table 4
ELFIN	Side Wall	2	Tantalum	Block	6.03	20.95	6.20	3.00	Yes	2980	Survives - See Table 4
ELFIN	Side Wall (Outer)	1	Tantalum	Block	4.21	14.65	6.20	3.00	Yes	2980	Survives - See Table 4
ELFIN	Side Wall (Inner)	2	Tantalum	Block	1.7	5.50	6.20	3.00	Yes	2980	Survives - See Table 4
ELFIN	Insulator Side	2	PEEK	Block	0.19	17.75	6.10	7.27	No	-	Demise
ELFIN	Spacer	1	Aluminum 6061-T6	Block	0.4	12.90	0.89	12.90	No	-	Demise
ELFIN	Wave Spring Washer	1	Beryllium Copper UNS C17200	Block	0.052	4.19	0.13	-	No	-	Demise
ELFIN	Insulator Back	1	PEEK	Block	0.19	12.90	0.84	12.90	No	-	Demise
ELFIN	Spacer MSX	1	PEEK	Block	0.03	12.95	0.26	12.95	No	-	Demise

CUBESAT	Name	Qty	Material	Body Type	Mass (g) (total)	Diameter/ Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp	Survivability
ELFIN	Mag Stage Front	1	Tantalum	Block	10.98	20.95	2.70	20.95	Yes	2980	Survives - See Table 4
ELFIN	Insulator Front	1	PEEK	Block	0.08	12.95	0.85	12.95	No	-	Demise
ELFIN	Cone Wall	4	Tantalum	Block	7.21	18.45	14.84	7.22	Yes	2980	Survives - See Table 4
ELFIN	Small WSW	2	Beryllium Copper UNS C17200	Block	0.03	7.62	0.13	-	No	-	Demise
ELFIN	RF Shield EFE	1	Aluminum 6061-T6	Block	3.72	7.92	36.02	9.86	No	-	Demise
ELFIN	RF Shield EFE Cover	1	Aluminum 6061-T6	Block	1.18	1.27	36.02	9.86	No	-	Demise
ELFIN	I Aperture Frame	1	Aluminum 6061-T6	Block	27.66	36.58	30.02	36.58	No	-	Demise
ELFIN	EPDD2 Fastener Widget	1	Aluminum 6061-T6	Block	0.86	5.59	13.50	7.62	No	-	Demise
ELFIN	Yoke	4	Hi Perm 49 Annealed	Block	0.9325	10.30	8.30	2.24	No	-	Demise
ELFIN	Spring Retainer	1	Aluminum 6061-T6	Block	0.89	22.80	8.30	2.35	No	-	Demise
ELFIN	I Aperture 1	1	Phosphor Bronze	Block	0.6	8.80	1.61	6.33	No	-	Demise
ELFIN	Outside Magnet	4	SmCo 2:17	Block	0.92	4.15	8.30	3.20	No	-	Demise
ELFIN	Auxiliary Shield M	2	Tantalum	Block	0.57	6.55	3.50	1.70	Yes	2980	Survives - See Table 4
ELFIN	Inside Magnet	2	SmCo 2:17	Block	1.84	8.30	3.20	8.30	No	-	Demise
ELFIN	Magnet Retainer	1	Aluminum 6061-T6	Block	1.87	20.50	8.30	8.10	No	-	Demise
ELFIN	Strawman Bridge	1	Aluminum 6061-T6	Block	1.546	25.40	7.94	4.95	No	-	Demise
ELFIN	I to E Standoff	1	Aluminum 6061-T6	Block	0.49	38.86	8.59	1.22	No	-	Demise
ELFIN	I Aperture 2	1	Phosphor Bronze	Block	6.73	24.00	1.61	24.00	No	-	Demise
ELFIN	I Aperture 2 Spacer	1	6063-T6	Block	2.88	24.00	8.29	24.00	No	-	Demise
ELFIN	I Aperture 3	1	Phosphor Bronze	Block	6.01	26.00	1.61	26.00	No	-	Demise
ELFIN	I Aperture 3 Spacer	1	6063-T6	Block	3.15	26.00	8.29	26.00	No	-	Demise
ELFIN	I Aperture 4	1	Phosphor Bronze	Block	6.88	31.00	1.61	31.00	No	-	Demise
ELFIN	I Aperture 4 Spacer	1	6063-T6	Block	3.61	31.00	8.29	31.00	No	-	Demise
ELFIN	I Aperture 5	1	Phosphor Bronze	Block	7.61	36.60	1.60	36.60	No	-	Demise
ELFIN	Sensor I	1	Polyimide/G-10/Silicon Dioxide/PEEK/Epoxy	Block	1.03	13.00	2.70	13.00	No	-	Demise
ELFIN	Stacer Can	1	Aluminum 6061-T6	Box	560	76.00	83.00	101.35	No	-	Demise
ELFIN	Payload Rods	4	#4 Titanium Threaded Rod	Rod	1	2.85	3.5	-	Yes	1650	Demise
ELFIN	EPD Digital 1 Board	1	FR4	PCB	58	1.57	93.22	86.61	No	-	Demise
ELFIN	EPD Digital 2 Board	1	FR4	PCB	58	1.57	93.22	86.61	No	-	Demise
ELFIN	EPD Extended Front End	1	FR4	PCB	10.6	49.91	69.6	10.77	No	-	Demise
ELFIN	EPD preamp	1	FR4	PCB	24	1.58	46.025	50.06	No	-	Demise
ELFIN	IDPU	1	FR4	PCB	62	1.57	93.23	86.61	No	-	Demise
ELFIN	SIPS	1	FR4	PCB	31.15	1.57	90.68	86.61	No	-	Demise

ELFIN	FGE (FGM Electronics PCBA)	1	FR4, various	85.05		92.66	92.28	23.69	No	-	Demise
ELFIN	FGE brace	1	Aluminum 6061-T6	Box	46.97	10.16	87.02	87.17	No	-	Demise

CUBESAT	Name	Qty	Material	Body Type	Mass (g) (total)	Diameter/ Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp	Survivability
ELFIN	FGE strap	1	Peek	Box	4.27	5.84	78.26	10.16	No	-	Demise
ELFIN	Torquer Coil - Y Spool		Peek		30.9	95.15	241.3	7.49	No	-	Demise
ELFIN	Torquer Coil - Y Wire		HTCCA	Wire	43.7	-	-	-	No	-	Demise
ELFIN	Torquer Coil - X Spool		Peek		31.9	85.73	243.84	16.64	No	-	Demise
ELFIN	Torquer Coil - X Wire		HTCCA	Wire	49.2	-	-	-	No	-	Demise
ELFIN	Battery Holders	2	Peek	Block	26	82	83.83	8.53	No	-	Demise
ELFIN	Batteries	4	Molicel ICR18650J Lithium-ion	Cylinder	46.39	18.4	65.4	-	No	-	Demise
ELFIN	Battery Arcs	4	Aluminum 6061-T6	Block	3.61	16.71	5.74	28.35	No	-	Demise
ELFIN	SBPCB	2	FR4	PCB	28.78	55.88	55.88	16.16	No	-	Demise
ELFIN	FCPCB	1	FR4	PCB	19	55.88	55.88	16.16	No	-	Demise
ELFIN	LETC1	1	FR4	PCB	17.4	55.88	55.88	16.16	No	-	Demise
ELFIN	LETC2	1	FR4	PCB	15.63	55.88	55.88	16.16	No	-	Demise
ELFIN	ACB	1	FR4	PCB	17.8	55.88	55.88	16.16	No	-	Demise
ELFIN	BETC	1	FR4	PCB	40.44	55.88	55.88	16.16	No	-	Demise
ELFIN	Radio	1	FR4/Aluminum	PCB	48.5	15	82	82	No	-	Demise

Appendix C. ElaNa-18 Component List by CubeSat: SurfSat

CUBESAT	Name	Qty	Material	Body Type	Mass (g) (total)	Diameter/ Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp	Survivability
SurfSat	SurfSat	1	-	-	-	-	-	-	-	-	Demise
SurfSat	Panel AA	1	6061 Aluminum	Plate	70.21	83	213	1.5	No	-	Demise
SurfSat	Panel BB	1	6061 Aluminum	Plate	70.01	83	213	1.5	No	-	Demise
SurfSat	Panel CC	1	6061 Aluminum	Plate	70.21	83	213	1.5	No	-	Demise
SurfSat	Panel DD	1	6061 Aluminum	Plate	70.01	83	213	1.5	No	-	Demise
SurfSat	Panel Bottom	1	6061 Aluminum	Plate	34.06	97	97	1.5	No	-	Demise
SurfSat	Panel Top	1	6061 Aluminum	Plate	34.06	97	97	1.5	No	-	Demise
SurfSat	Corner Bracket b	2	6061 Aluminum	Rail	37.04	16.63	213	16.63	No	-	Demise
SurfSat	Corner Bracket c	2	6061 Aluminum	Rail	37.74	16.63	213	16.63	No	-	Demise
SurfSat	Corner Block A	4	6061 Aluminum	Block	4.34	16.63	16.63	14.37	No	-	Demise
SurfSat	Corner Block A2	2	6061 Aluminum	Block	7.48	16.63	16.63	25.85	No	-	Demise
SurfSat	Corner Block Separation Spring	2	6061 Aluminum	Block	3.98	16.63	16.63	14.37	No	-	Demise
SurfSat	70cm Antenna	2	Steel	Wire	1.4	1.2	162.14	-	No	-	Demise
SurfSat	Antenna Hook	2	Aluminum	Hook	<1 g each	10.16	17	6.36	No	-	Demise
SurfSat	Antenna Standoff	4	Brass	Rod	9.02	4.75	3.3	-	No	-	Demise
SurfSat	Antenna Swing Assembly	2	PCB/Plastic	Plate	4.5	16	23.17	17.1	No	-	Demise
SurfSat	Brass swing screw	2	Brass	Rod	1	4.76	17.46	-	No	-	Demise
SurfSat	NiChrome Wire Mech Assembly	4	Teflon/Steel	Plate	4.39	30	10	12.6	No	-	Demise
SurfSat	Langmuir Probe support	1	Steel	Tape	15.11	12.7	216.74	25.4	No	-	Demise
SurfSat	Langmuir Probe cable	1	Coaxial cable	Cable	2.25	2.8	220	-	No	-	Demise
SurfSat	Solar Panel (Side)	4	PCB/Glass	Plate	27.98	82.55	95.25	2	No	-	Demise
SurfSat	Solar Panel (Top)	2	PCB/Glass	Plate	30.13	93.98	93.98	2	No	-	Demise
SurfSat	Limit switch	2	Plastic	Block	1	5.08	12.7	10.2	No	-	Demise
SurfSat	Switch Plunger	2	Steel	Cylinder	<1 g each	1.78	6.35	-	No	-	Demise
SurfSat	Separation Spring	2	Stainless Steel	Cylinder	<1 g each	3.45	11.31	-	No	-	Demise
SurfSat	Mounting Plate	4	6061 Aluminum	Plate	42	82.55	95.25	1	No	-	Demise
SurfSat	Sample Plate 1	1	6061 Aluminum	Plate	7.62	63.5	63.5	0.7	No	-	Demise
SurfSat	Paint sample	1	AZ-400-LSW paint	-	<1 g	63.5	63.5	0.6	No	-	Demise
SurfSat	Sample Plate 2	1	6061 Aluminum	Plate	7.62	63.5	63.5	0.7	No	-	Demise
SurfSat	Paint sample	1	AZJ-4020 paint	-	<1 g	63.5	63.5	0.6	No	-	Demise
SurfSat	Sample Plate 3	1	6061 Aluminum	Plate	7.62	63.5	63.5	0.7	No	-	Demise
SurfSat	Kapton Tape sample	1	Kapton Tape	-	<1 g	63.5	63.5	0.6	No	-	Demise
SurfSat	Sample Plate 4	1	Anodized Aluminum	Plate	7.62	63.5	63.5	1	No	-	Demise
SurfSat	Permanent Magnet	1	Alnico	Block	1.7	6.15	12.7	3.13	No	-	Demise

SurfSat	Hysteresis Rod	2	Permalloy 80	Cylinder	0.618	1	90	-	No	-	Demise
SurfSat	Raspberry Pi CCDR	2	PCB	Plate	70	87	125	14	No	-	Demise
SurfSat	Picoscope Oscilloscope Board	1	PCB	Plate	110	95.1	89.1	10.9	No	-	Demise
SurfSat	Langmuir probe board	1	PCB	Plate	30	125	104	22	No	-	Demise
SurfSat	Electrometer board	1	PCB	Plate	100	76.7	80.4	12.3	No	-	Demise
SurfSat	Antenna Deployment and Link	1	PCB	Plate	28.5	78.78	91.38	1.57	No	-	Demise
SurfSat	Comm Board	2	PCB	Plate	28.5	94	94	10	No	-	Demise
SurfSat	Battery Board	1	PCB	Plate	21.64	94	94	10	No	-	Demise
SurfSat	Battery charge tracking board	1	PCB	Plate	47.5	94	94	10	No	-	Demise
SurfSat	C&DH Board	1	PCB	Plate	13.29	94	94	10	No	-	Demise
SurfSat	Electronics Bottom Mounting Plate	1	6061 Aluminum	Plate	33.54	97	97	1.6	No	-	Demise
SurfSat	Fastening screw	58	Steel	Cylinder	-	-	-	-	No	-	Demise
SurfSat	Fastening screw	2	Steel	Cylinder	-	-	-	-	No	-	Demise
SurfSat	Electronics board standoff	28	Steel	Cylinder	-	-	-	-	No	-	Demise
SurfSat	Electronics board standoff	16	Steel	Cylinder	-	-	-	-	No	-	Demise
SurfSat	Limit switch bolt 1	2	Steel	Cylinder	-	-	-	-	No	-	Demise
SurfSat	Limit switch bolt 2	2	Steel	Cylinder	-	-	-	-	No	-	Demise
SurfSat	Gecko Connector	6	PCB	Plate	-	-	-	-	No	-	Demise
SurfSat	Coaxial cable	10	Copper alloy	-	-	-	-	-	No	-	Demise