ELVL-2016-0044282 (Rev 2 FCC)
September 21, 2016

Orbital Debris Assessment for The CubeSats on the JPSS-1 /ELaNa-XIV Mission per NASA-STD 8719.14A

Signature Page

Justin Treptow, Analyst, NASA KSC VA-H1

Scott Higginbotham, Mission Manager, NASA KSC VA-C

National Aeronautics and
Space Administration

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

ELVL-2016-0044282

Reply to Attn of: VA-H1 September 21, 2016

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

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

SUBJECT: Orbital Debris Assessment Report (ODAR) for the ELaNa-XIV Mission (Rev 2 FCC)

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 7920-10 / JPSS-1 Spacecraft Mission, ULA-TP-15-096, July 21, 2015.
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

Update: Rev 2 has removed GoldenEagle-1 from the manifest and replaces it with MakerSat-0 as primary replacement and DAVE as the back up. JPSS-1 launch date has also been updated to reflect most recent ILC.

The intent of this report is to satisfy the orbital debris requirements listed in ref. (a) for the ELaNa-XIV auxiliary mission launching in conjunction with the JPSS-1 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-XIV auxiliary payload mission flown on JPSS-1. The 6 CubeSats comprising the ELaNa-XIV mission and back up 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	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 13.8 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 ELaNa-XIV mission

Section 1: Program Management and Mission Overview

The ELaNa-XIV 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:

Buccaneer: Ian Cartwright, Principle Investigator; David Lingard ,Project Manager

EagleSat: Gary Yale, Principle Investigator; Clayton Jacobs ,Project Manager

MakerSat-0: Dr. Joshua Griffin, Principle Investigator; Braden Grim, Project Manager

MiRaTA: Kerri Cahoy and William Blackwell, Principle Investigator; Vincent Leslie ,Project Manager

RadFXSat: Brian Sierawski ,Principle Investigator; Gerald Buxton ,Project Manager

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

Program Milestone Schedule	
Task	Date
CubeSat Selection	April 5, 2015
CubeSat Build, Test, and Integration	November 4, 2016
MRR	December 6, 2016
CubeSat Integration into P-PODs	January 10, 2017
CubeSat Delivery to VAFB	March 3, 2017
Launch	March 16, 3027

Figure 1: Program Milestone Schedule

The ELaNa-XIV mission will be launched as an auxiliary payload on the JPSS-1 mission on a Delta II 7920-10 launch vehicle from Space Launch Complex 2 West (SLC-2W) at Vandenberg Air Force Base (VAFB). ELaNa-XIV, will deploy 5 pico-satellites (or CubeSats). The CubeSat slotted position is identified in Table 2: ELaNa-XIV CubeSats. The ELaNa-XIV manifest includes: Buccaneer, EagleSat, MakerSat-0, MiRaTA and, RadFXSat, and DAVE (back up). The current launch date is in Mach 16, 2017**.** The 5 CubeSats will be ejected from a PPOD carrier attached to the launch vehicle, placing the CubeSats in an orbit approximately 440 km X 811 km at inclination of 97.7 deg (ref. (c)).

The CubeSat standard form ranges in sizes 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 universities and government agencies and each have their own mission goals.

Section 2: Spacecraft Description

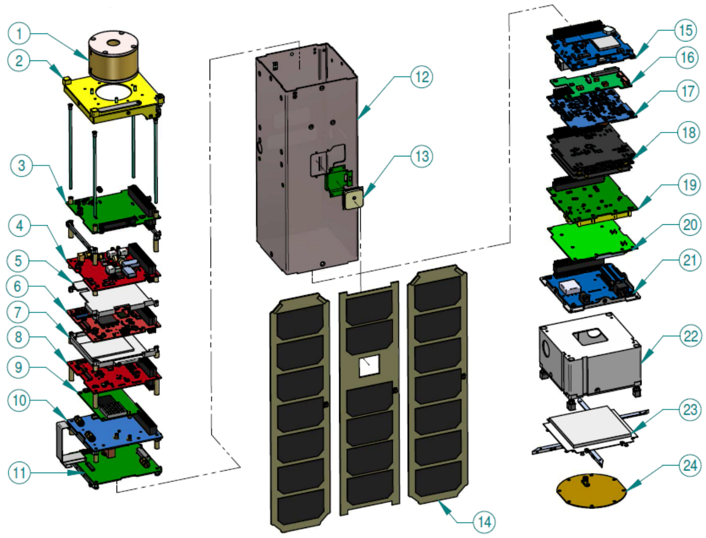
There are five CubeSats flying on the ELaNa-XIV and one back up. The CubeSats will be deployed out of 3 PPODs, as shown in Table 2: ELaNa-XIV CubeSats below.

Table 2: ELaNa-XIV CubeSats

PPOD Slot	CubeSat Quantity	CubeSat size	CubeSat Names	CubeSat Masses (kg)
P-POD #1	3	1U (10 cm X 10 cm X 10.66 cm)	EagleSat	1.1
		1U (10 cm X 10 cm X 10 cm)	MakerSat-0	1.15
		1U (10 cm X 10 cm X 10 cm)	RadFXSat	1.32
P-POD #2	1	3U (10 cm X 10 cm X 32.5 cm)	Buccaneer	3.98
P-POD #3	1	3U (10 cm X 10 cm X 32.4 cm)	MiRaTA	4.19
Back Up	1	1U (10 cm X 10 cm X 11.35 cm)	DAVE	1.4

The following subsections contain descriptions of these 6 CubeSats.

Buccaneer 1.0 – DST Group/UNSW Canberra – 3U+



ITEM	COMPONENT
1	Buccaneer HF Antenna Deployment Module
2	Buccaneer 3U+ End Cap
3	Buccaneer Payload Interface Module
4	Buccaneer HF Analogue Front End Module
5	Buccaneer HFPBEM Top Heatsink
6	Buccaneer HF Processing Back End Module
7	Buccaneer HFPBEM Bottom Heatsink
8	Buccaneer Payload Management Module
9	GPS Module
10	GPS Interface Module
11	Buccaneer Payload Bus Adaptor Module
12	Pumpkin Spacecraft Chassis
13	GPS Antenna
14	Pumpkin Solar Panels
15	OBC (CubeSat Kit Motherboard)
16	OBC (PMM with PIC24 Processor)
17	ClydeSpace EPS
18	ClydeSpace Battery
19	UHF Radio
20	S-Band Radio
21	ADCS Interface Board
22	MAI-400 ADACS
23	UHF Antenna
24	S-Band Antenna

Figure 2: Buccaneer Expanded View

Buccaneer is a 3U+ CubeSat that will collect High Frequency (HF) signals in space with a 3.2m open-ended bow tie antenna. The objective is to first test the feasibility of such a large antenna in space, and secondly to receive and process signals from Australian Defence's over-the-horizon radars, leading to improved calibration. The first Buccaneer mission that is part of ELaNa-14 is known as the Buccaneer Risk Mitigation Mission (BRMM). The intention is to later launch a second Buccaneer mission, after technical and programmatic risk has been retired during the BRMM.

The Buccaneer mission is being progressed as a partnership between:

1. The Defence Science and Technology (DST) Group, part of the Australian Department of Defence, and
2. The University of New South Wales (UNSW), Canberra campus.

In addition, the Australian National University (ANU) in Canberra will provide support with environmental stress screening through agreements that they have in place with UNSW Canberra. The National Reconnaissance Office (NRO) is sponsoring launch of the Buccaneer CubeSat.

The HF receiver payload will be designed and manufactured by DST Group. It consists of:

- A large HF antenna housed inside the tuna can of the 3U+ structure (1, 2 &3), including a PCB to support deployment of the antenna, and connection to ground support equipment.
- A front end module to receive the raw HF signal and perform analogue to digital conversion.
- A back end module to store the raw HF data (solid state disks) and perform digital signal processing (Field Programmable Gate Array).
- A KEA GPS unit developed by General Dynamics Corporation (New Zealand), and an associated interface board that produces a low phase noise 120 MHz clock signal for analogue to digital conversion of the received raw HF signal.

- A payload management module that communicates with the spacecraft bus, controls the other payload modules, acts as a time server, and has a watchdog timer, and
- A payload bus adaptor module that interfaces with the CubeSat bus, contains a camera (developed by UNSW Canberra) to confirm correct deployment of the HF antenna, and hosts the space vehicle's magnetometer.

The spacecraft bus will be integrated by Pumpkin Inc. and consists of:

- Pumpkin Solar Panels, ClydeSpace EPS and batteries
- Astronautical Development UHF transceiver and ISISpace UHF antenna
- F-SATI S-Band transmitter and patch antenna
- MAI-400 ADCS unit from Maryland Aerospace Incorporated
- Pumpkin on-board computer unit
- Pumpkin chassis

Upon deployment from the P-POD, the Buccaneer flight computer will power up and start counting down a timer. After 45 minutes, the UHF antenna will deploy and a UHF beacon will be activated. For the first few passes, the ground station operators will attempt communications to perform checkouts of the spacecraft. Approximately 6 days from deployment, the ground station operators will command the spacecraft to deploy the solar panels. Approximately, 2 weeks from deployment, the ground station operators will command the spacecraft to deploy the HF antenna. The spacecraft will then be operational for at least 1 year.

The CubeSat structure is made of Aluminium 6061-T6. It contains standard Commercial Off The Shelf (COTS) materials, electrical components, PCBs and solar cells. The HF antenna payload and UHF antenna used for commanding/telemetry will use spring steel. The GPS patch antenna is ceramic.

There are no pressure vessels, or hazardous / exotic materials.

The electrical power storage system will be a COTS 30Whr common lithium-ion polymer battery purchased from Clyde Space. It has over-charge/current protection circuitry and will carry the UL-listing number BBCV2.MH13654.

EagleSat-1 – Embry-Riddle Aeronautical University, Prescott – 1U

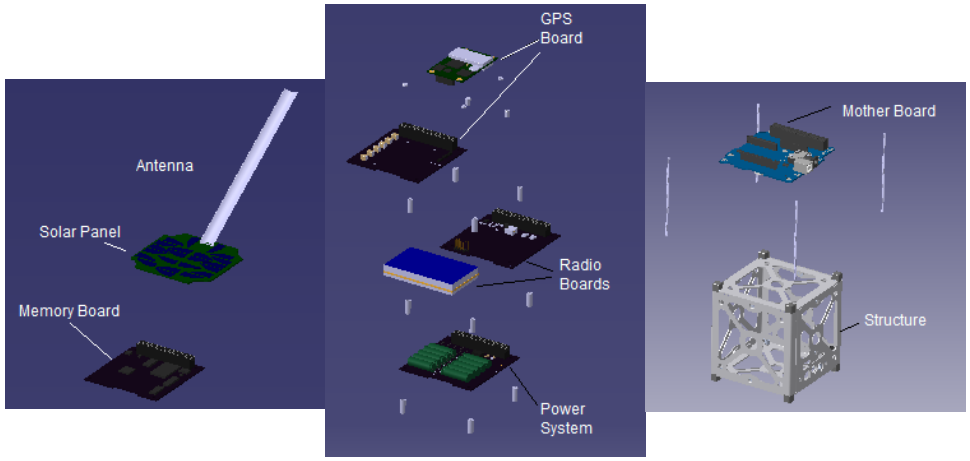


Figure 3: EagleSat-1 Expanded View

EagleSat-1, a 1U satellite built by the Embry-Riddle Aeronautical University EagleSat Satellite Design Team, will attempt to measure the decay of the satellite's orbit over time by the means of an unlocked GPS receiver while gauging the effect of radiation and other natural phenomenon on flash based memory technologies in the space environment. The major scientific payload will be the flash based memory testing. The major subsystems comprising the satellite are structures, power, communications, memory experiment, gps experiment and on board computer (OBC). The radio transmitter within the satellite has been donated by Wood & Douglas of the UK.

Upon deployment from the P-POD, EagleSat-1 will enter sleep mode and begin to charge its energy bank until a charge threshold is reached. After this threshold is met, the satellite will begin a 60 minute countdown. After 60 minutes, the antenna will deploy, followed by a repeating UHF beacon. Ground station operators will attempt communication after a beacon is received at the ground and will verify system health for the first few passes. Normal satellite operation and occasional data downlink will continue for at least one year.

The CubeSat structure is fabricated from 5052-H32 aluminum sheet metal. It contains all standard commercial off the shelf (COTS) materials, electrical components, PCBs, and solar cells. The UHF radio uses a deployable tape measure antenna that stows along the surface of the structure. Deployment occurs with the heating of a resistor which cuts a piece of thread.

There are no pressure vessels, hazardous or exotic materials contained within the CubeSat.

The electrical power storage system consists of a parallel-series bank of supercapacitors. The capacitors carry the UL-listing number BBBG2.MH46887.

MakerSat-0 – Northwest Nazarene University – 1U

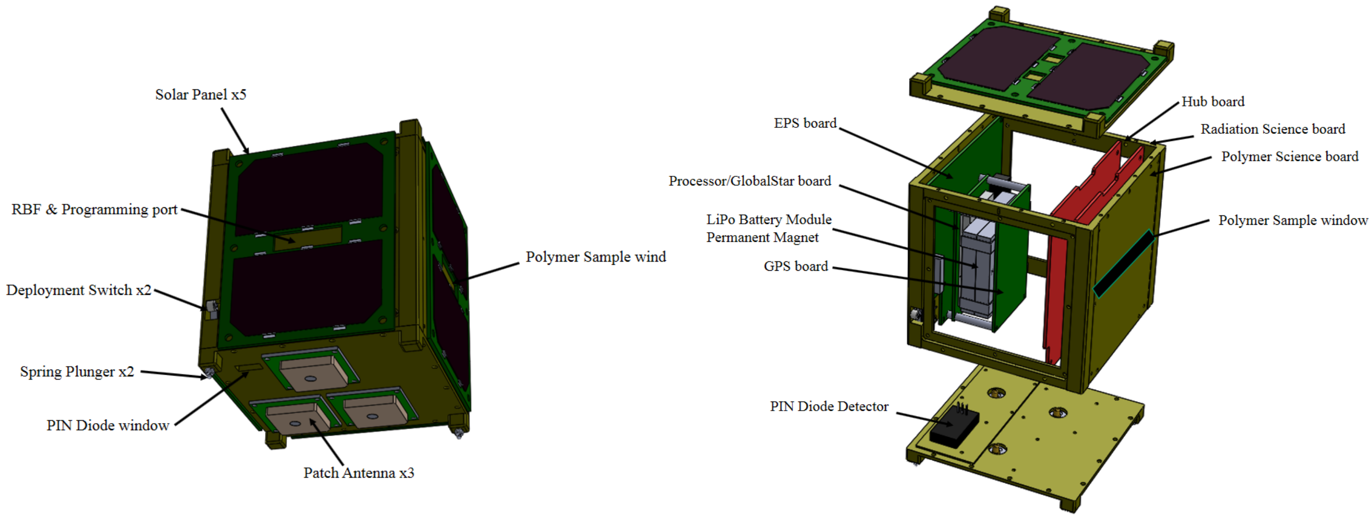


Figure 4: MakerSat-0 Expanded View

MakerSat-0 will study the viability of various 3D printed polymers for in-space manufacturing of spacecraft structures. It will also demonstrate a multi-user architecture for sharing the satellite core systems among several science team payloads.

Upon deployment from the P-POD, MakerSat will power up and start a 45 minute time after which its GlobalStar radio will be activated. Health beacon data will be transmitted every 30 minutes and science payload tests will be run round robin on a 50 minute cycle.

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 GlobalStar radio uses ceramic patch antennas. Four half gram samples of ABS, Nylon, PLA, and ULTEM plastic are inside one science experiment.

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 lithium polymer batteries and circuitry are from Tenergy 3.7V 2200mAh (925050) Battery - UL Listed.

MiRaTA – MIT Lincoln Laboratory – 3U

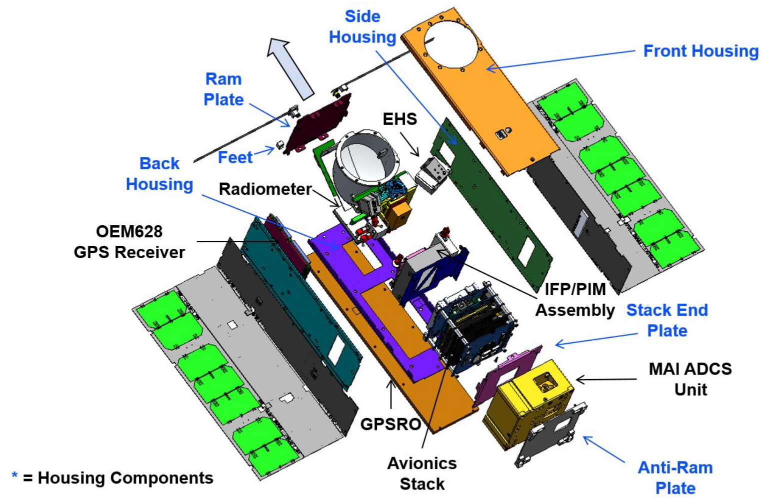


Figure 5: MiRaTA Expanded View

Microwave Radiometer Technology Acceleration (MiRaTA) is a 3U CubeSat mission which will demonstrate technology and advance TRL for three key microwave radiometer technologies: 1) Intermediate Frequency Processor, 2) G-band mixer, and 3) calibration using GPS-RO measurements. It will accomplish this with its two primary payloads: a multi- band radiometer, built by MIT Lincoln Laboratory and UMass Amherst, and the Compact TEC Atmospheric GPS System (CTAGS), built by Aerospace Corp.

The supporting spacecraft bus is built by graduate students from the MIT Space Systems Laboratory. The major components of the power, communications, and ADCS subsystems are designed and built by commercial aerospace vendors, while the components of the avionics, structures and thermal subsystems are designed by graduate students with manufacturing done through external fabrication specialists. The primary sponsor of the MiRaTA mission is the NASA Earth Science Technology Office (ESTO) through the In-Space Validation of Earth Science Technologies (InVEST) program.

Upon deployment from the P-POD, MiRaTA will power up and start counting down timers. At 45 minutes, the solar panels and antennas will be deployed, and the backup radio will start beaconing. During the first few passes, the ground station operators will attempt communications to perform checkouts of the spacecraft. Approximately 4 days from launch, payload tests will begin and continue for at least six months.

The CubeSat structure is made of Aluminum 6061-T6 and Aluminum 5052-H32. It contains standard commercial off-the-shelf (COTS) materials, electrical components, PCBs and solar cells. The CTAGS payload uses a ceramic patch antenna.

There are no pressure vessels, hazardous or exotic materials.

The electrical power storage system consists of common lithium-ion batteries with over-charge/current protection circuitry. The lithium batteries carry the UL-listing number BBCV2.MH 13654.

RadFxSat – Vanderbilt University / AMSAT – 1U

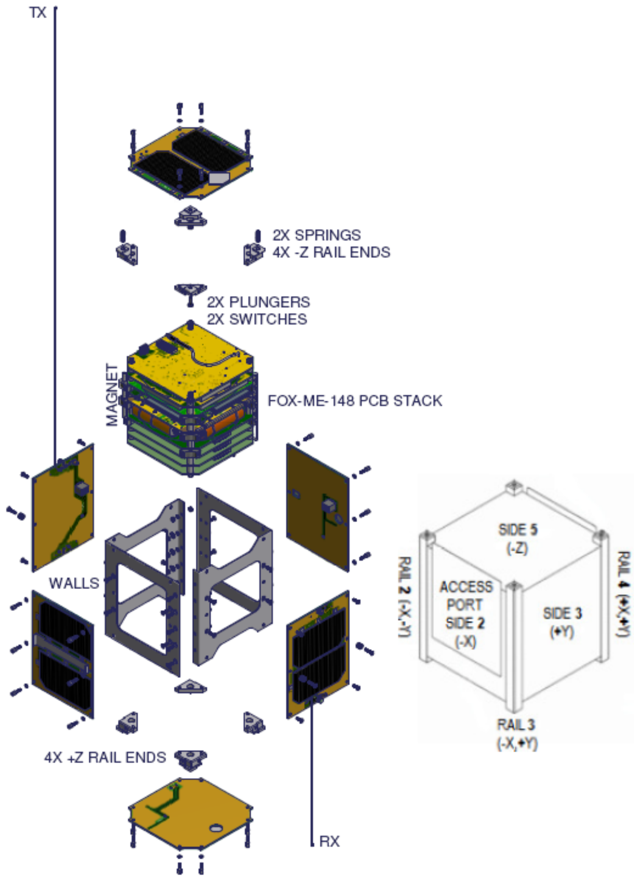


Figure 6: RadFXSat Expanded View

RadFxSat is a 1U CubeSat designed by Vanderbilt University and AMSAT. It is controlled by AMSAT. Its mission has two objectives: collect data on the effects of space radiation on 28nm bulk CMOS static random access memory for the purpose of validating single-event error rate predictions, and two-way FM communications transponder in the amateur radio band.

CONOPS (abbreviated):

P-POD Ejection + 00:00 mm:ss - CubeSat deployed from the P-POD and CubeSat switches indicate successful deployment. IHU starts. Solar Panels may charge battery.
P-POD Ejection + 50:05 mm:ss - transmit antenna deployed (fishing line melt anticipated)
P-POD Ejection + 50:15 mm:ss - receive antenna deployed (fishing line melt anticipated)
P-POD Ejection + 50:21 mm:ss - transmission may begin

Design life is 5-15 years. Typical operations include U/V amateur radio communications and low duty-cycle telemetry. Operations are planned until re-entry.

The bent sheet metal structure is Aluminum 5052-H32. Small-machined parts are Aluminum 6061-T6, Copper 110, black Delrin, or G10 Fiberglass. The four long #4 threaded rods, and all #2 screws and jack posts are stainless steel. The PCB Stack includes experiments and avionics. Select ICs have small pieces of Tantalum as radiation shielding. The Rx and Tx boards have copper RF Shields. A large sheet of Lead is used as ballast on the bottom side of MPPT. There is a Neodymium magnet approximately centered in Rail 2, and two Permalloy hysteresis rods bottom side of Battery.

There are no pressure vessels or hazardous materials on the satellite.
No debris is released during deployment of antennas (both ends of fishing lines are tied to satellite parts).

The battery consists of six commercial off the shelf (COTS) NiCad “A” size batteries (Sanyo KR1400AE; UL listing N/A; total capacity 11.5 Watt hours).

DAVE CubeSat Description, Cal Poly – 1U

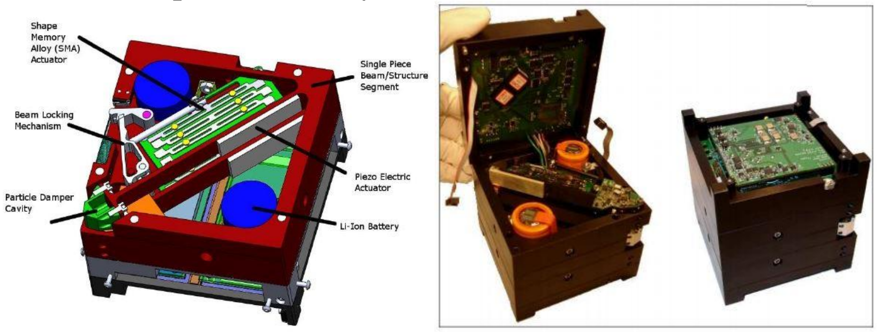


Figure 7: DAVE Expanded View

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.

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.

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.

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

There are 2x UL listed 3.6V 4000mAh Lithium-Ion 26650 batteries connected in parallel. The UL listing number is MH61586. There is battery protection circuitry and over-charge protection.

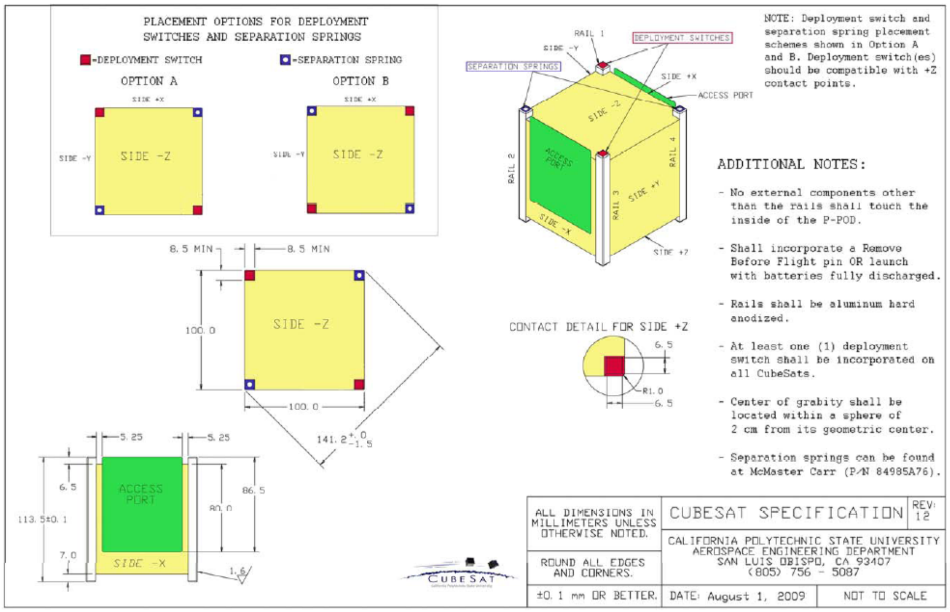


Figure 8: 1U CubeSat Specification

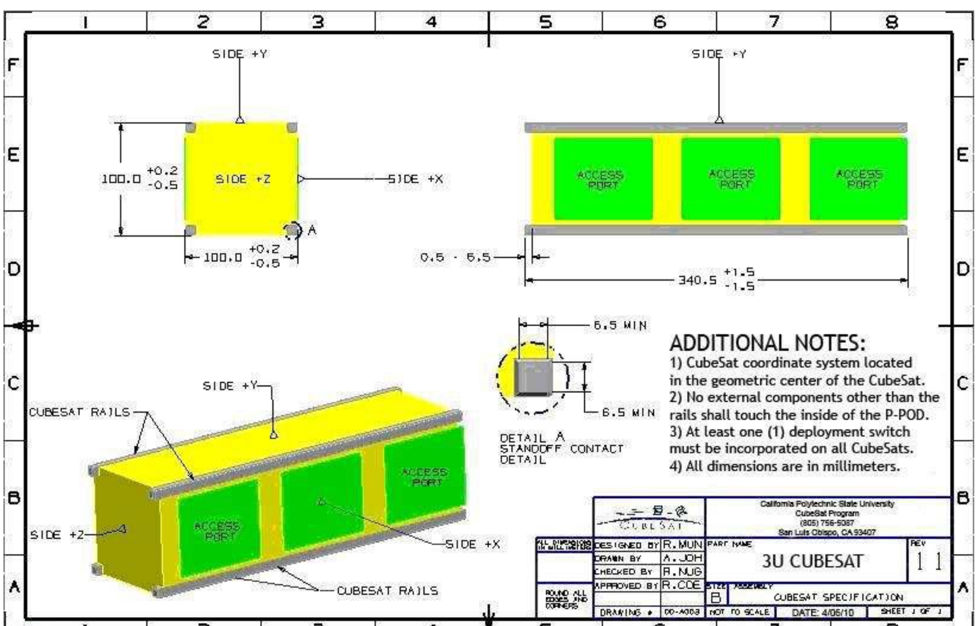


Figure 9: 3U CubeSat Specification

Section 3: Assessment of Spacecraft Debris Released during Normal Operations

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

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

No releases are planned on the ELaNa-XIV 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-XIV 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 low earth orbit environment is negligible (ref (h)).

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

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

Assessment of spacecraft compliance with Requirements 4.4-1 through 4.4-4 shows that with a lifetime of 13.8 years maximum the ELaNa-XIV CubeSat is compliant.

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

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

The largest mean cross sectional area (CSA) among the five CubeSats, is that of the Buccaneer CubeSat (10 X 10 X 32.5 cm):

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

Equation 1: Mean Cross Sectional Area for Convex Objects

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

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 dimensions used in these calculations

The Buccaneer CubeSat has an orbit at deployment of 440 km perigee altitude by 811 km apogee altitude, with an inclination of 97.7 degrees. With an area to mass (3.98 kg) ratio of 0.046 m^2/kg, DAS yields 5.2 years for orbit lifetime for its deployed state. Even with the variation in CubeSat design and orbital lifetime ELaNa-XIV CubeSats see an average of 0.00000 probability of collision. Buccaneer, with the largest cross sectional area will see the highest 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	Buccaneer	EagleSat	MakerSat-0	MiRaTA	RadFXSat	DAVE (Back Up)
	Mass (kg)	3.98	1.1	1.15	4.19	1.32	1.4
Stowed	Mean C/S Area (m^2)	0.038	0.016	0.015	0.0374	0.015	0.016
Stowed	Area-to Mass (m^2/kg)	0.009	0.014	0.013	0.0089	0.011	0.011
Stowed	Orbital Lifetime (yrs)	8.5	7.4	7.6	13.8	8.5	8.0
Stowed	Probability of collision (10^X)	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Deployed	Mean C/S Area (m^2)	0.183	0.021	0.015	0.0385	0.0153	0.016
Deployed	Area-to Mass (m^2/kg)	0.046	0.019	0.013	0.0092	0.012	0.011
Deployed	Orbital Lifetime (yrs)	5.2	6.6	7.6	12.5	8.3	8.0
Deployed	Probability of collision (10^X)	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Solar Flux Table Dated 10/14/2015

The probability of any ELaNa-XIV 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-XIV to be compliant. Requirement 4.5-2 is not applicable to this mission.

Section 6: Assessment of Spacecraft Post-mission Disposal Plans and Procedures

All ELaNa-XIV 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 post-mission disposal is not applicable. Disposal is achieved via passive atmospheric reentry.

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

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

Equation 3: Area to Mass

$$\frac{0.0374m^2}{4.19kg} = \ 0.0089\frac{m^2}{kg}$$

Equation 4: Area to Mass Calculation of MiRaTA (Stowed)

MiRaTA has the smallest Area-to-Mass ratio and as a result will have the longest orbital lifetime (worst cast time to deorbit). 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: 440 km maximum perigee 811 km maximum apogee altitudes with an inclination of 97.7 degrees at deployment in January 20 of 2017. An area to mass ratio of 0.0089 m^2/kg for the MiRaTA CubeSat was imputed. DAS 2.0.2 (using a solar flux file dated 10/14/2015) yields a 13.8-year orbit lifetime for MiRaTA 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-XIV was performed. The assessment used DAS 2.0.2, a conservative tool used by the NASA Orbital Debris Office to verify Requirement 4.7-1. The analysis is intended to provide a bounding analysis for characterizing the survivability of a CubeSat's component during re-entry. For example, when DAS shows a component surviving reentry it is not taking into account the material ablating away or charring due to oxidative heating. Both physical effects are experienced upon reentry and will decrease the mass and size of the real-life components as the reenter the atmosphere, reducing the risk they pose still further.

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

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

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

Table 4: ELaNa-VIX Survivability Analysis

CubeSat	High Temp Component	Material	Mass (g)	Demise Alt (km)	KE (J)
Buccaneer	HF Antenna	Spring Steel ASTM A228	110	0	8
Buccaneer	AntS UHF Antenna	Spring Steel ASTM A228	10	76.4	0
Buccaneer	GPS Antenna	Ceramic	50	72.6	0
Buccaneer	Fasteners / Screws	Stainless Steel	0.3	77.9	0
Buccaneer	Solar Panel Clips	Stainless Steel	1	77.9	0
EAGLESAT-1	Antenna + Panels	Steel Tape Measure	29	0	2
EAGLESAT-1	GPS Patch Antenna	Ceramic	10	73.1	0
GoldenEagle-1	Antennae	Steel	1.1	0	0
GoldenEagle-1	Sep Switches	Stainless Steel	0.1	77.8	0
GoldenEagle-1	Antennae counter balance	Steel	1.1	0	0
GoldenEagle-1	Fasteners	Stainless Steel	0.3	77.9	0

Table 5: ELaNa-VIX Survivability Analysis Continued

CubeSat	High Temp Component	Material	Mass (g)	Demise Alt (km)	KE (J)
MiRaTA	Fasteners/Screws	Stainless Steel	0.25	77.9	0
RadFXSat	PCB Stack screws	Stainless steel	1.3	77.6	0
RadFXSat	Magnet	Neodymium	5.3	77.8	0
RadFXSat	Tantalum Radiation Shield	Tantalum	3.6	0	2
RadFXSat	Tantalum Radiation Shield	Tantalum	2.3	0	1
RadFXSat	Tantalum Radiation Shield	Tantalum	1.9	0	0
RadFXSat	Tantalum Radiation Shield	Tantalum	1.1	0	0
RadFXSat	Tantalum Radiation Shield	Tantalum	0.8	0	0
RadFXSat	Tantalum Radiation Shield	Tantalum	0.8	0	0
RadFXSat	Tantalum Radiation Shield	Tantalum	0.8	0	0
RadFXSat	Tantalum Radiation Shield	Tantalum	0.7	0	0
RadFXSat	Tantalum Radiation Shield	Tantalum	0.6	0	0
RadFXSat	Tantalum Radiation Shield	Tantalum	0.3	0	0
RadFXSat	Tantalum Radiation Shield	Tantalum	0.1	0	0
MakerSat-0	Spring Plungers	Stainless Steel	1	75.6	0
MakerSat-0	RBF Pin	Stainless Steel	3	77.4	0
MakerSat-0	Fasteners / Spacers	Stainless Steel	1	75.4	0
MakerSat-0	Magnet & Damping	Perm Mag MU-Metal	10	70.3	0
DAVE	Antenna Wire	Nickel Titanium	2.5	0	0
DAVE	Cavity Caps	316 Stainless Steel	10.5	73.7	0
DAVE	Tungsten Crystalline Powder*	Tungsten	20	0	0
DAVE	SMA Actuators Boards	Nickel Titanium	0.5	77.8	0
DAVE	Locking springs	302 Stainless	3	76.8	0
DAVE	Fasteners	18-8 Stainless	35	76.8	0

A significant number of the high temperature components demise upon reentry. The components that DAS conservatively identifies as reaching the ground have less than 15 joules of kinetic energy. No high temperature 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.

Components, reported by DAS to have a demise altitude of 0 km and kinetic energy of 0J, can be assumed to have energy less than one joule as DAS does not supply decimal result.

Through the method described above, Table 4: ELaNa-VIX Survivability Analysis, and the full component lists in the Appendix all CubeSats launching under the ELaNa-XIV mission are conservatively shown to be in compliance with Requirement 4.7-1 of NASA-

STD-8719.14A.

Section 8: Assessment for Tether Missions

ELaNa-XIV CubeSats will not be deploying any tethers.

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

Section 9-14

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

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

/original signed by/

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

cc: VA-H/Mr. Carney
VA-H1/Mr. Beaver
VA-H1/Mr. Haddox
VA-G2/Mr. Atkinson
VA-G2/Mr. Marin
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-XIV Component List by CubeSat: Buccaneer

Name	Qty	Material	Body Type	Mass (g)	Diameter/ Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp	Survivability
Buccaneer RMM	1		3U+							
CubeSat Chassis	1	Aluminium 5052-H32	Box	320	100	100	325	No	-	Demise
Top/Bottom Plate	2	Aluminium 5052-H32	Square	62	100	100	5	No	-	Demise
HF Antenna	4	Spring Steel ASTM A228	Ribbon	110	19	1730	1	Yes	1500	Survives to the ground with 8J of energy
Tuna Can (HF Antenna Mount)	1	Ketron PEEK-1000 / Aluminium 6061-T6	Cylinder	120	64	-	36	No	-	Demise
AntS UHF Antenna	4	Spring Steel ASTM A228	Ribbon	10	7	100	1	Yes	1500	Demise at 76.4km Altitude
S-Band Patch Antenna	1	Aluminium 8062	Cylinder	50	76	-	4	No	-	Demise
GPS Antenna	1	Ceramic	Square	50	25	25	8	Yes	1400	Demise at 72.6km Altitude
Side Panels/Deployable Panels	6	FR-4 Fiberglass / Copper	Rectangular	50	100	325	2	No	-	Demise
UTJ Solar Cells	23	GaAs	Rectangular	0.1	50	25	0.1	No	-	Demise
Wing Hinges	8	Aluminum 6061-T6	Plate	5	8	30	3	No	-	Demise
Fasteners / Screws	60	Stainless Steel	Rods	20	1.6	5	-	Yes	1500	Demise at 77.9km Altitude
Sep Switches Plungers	3	Aluminum 6061-T6	Rod	1	2	20	-	No	-	Demise
CubeSat Feet	4	Aluminum 6061-T6	Cube	1	8.5	8.5	6.5	No	-	Demise
Solar Panel Connectors	8	Polyamide	Rectangular	1	1	5	5	No	-	Demise
Kapton Tape	-	Polyimide	Coating	-	-	-	-	No	-	Demise
Solar Panel Clips	8	Stainless Steel	Clip	1	5	5	0.5	Yes	1500	Demise at 77.9km Altitude
Pumpkin Flight Computer	1	FR-4 Fiberglass	Square	100	100	100	20	No	-	Demise
Clyde Space 30WHr Battery	1	FR-4 Fiberglass	Square	100	100	100	20	No	-	Demise
Clyde Space EPS	1	FR-4 Fiberglass	Square	100	100	100	20	No	-	Demise
MAI-400 ADCS Unit	1	Aluminum 6061-T651	Cube	600	100	100	56	No	-	Demise
UHF Transceiver Radio	1	FR-4 Fiberglass	Square	100	100	100	20	No	-	Demise
S-Band Transmitter Radio	1	FR-4 Fiberglass	Square	100	100	100	20	No	-	Demise
ADCS Interface Module	1	FR-4 Fiberglass	Square	100	100	100	20	No	-	Demise
Solar Interface Module	1	FR-4 Fiberglass	Square	100	100	100	20	No	-	Demise
Magnetometer	1	FR-4 Fiberglass	Square	100	100	100	20	No	-	Demise

Name	Qty	Material	Body Type	Mass (g)	Diameter/ Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp	Survivability
Payload GPS Board	1	FR-4 Fiberglass	Square	100	100	100	20	No	-	Demise
Payload ADC Board	1	FR-4 Fiberglass	Square	100	100	100	20	No	-	Demise
Payload Backend Board	1	FR-4 Fiberglass	Square	100	100	100	20	No	-	Demise
Payload Antenna Board	1	FR-4 Fiberglass	Circular	100	100	100	20	No	-	Demise
Payload Bus Interface Board	1	FR-4 Fiberglass	Square	100	100	100	20	No	-	Demise
Antenna Cabling/Harness	5	Coax	Coax	-	2.5	150	-	No	-	Demise
Standoffs	1	Aluminium 6061-T6	Misc	1	7	20	-	No	-	Demise
Threaded Rods	4	Aluminium 6061-T6	Rods	8	3	150	-	No	-	Demise
Seperation Switches	3	Thermalplastic UL94HB	Rectangular	5	5	20	10	No	-	Demise
CSK RBF Bracket	1	Aluminium 6061-T6	Bracket	1	35.4	59.7	18.4	No	-	Demise
Stack Spacers	20	Aluminium 6061-T6	Tubular Rod	1	6	15	-	No	-	Demise

Appendix B. ELaNa-XIV Component List by CubeSat: EagleSat

Name	Qty	Material	Body Type	Mass (g)	Diameter/ Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp	Survivability
EagleSat-1	1			~757.4						
Structure Main	1	Aluminum 7075	Box	184.6	100	100	106.6	No	-	Demise
Structure Plate	1	Aluminum 7075	Square	55.8	100	100	73.25	No	-	Demise
Antenna + Panels	1	Steel Tape Measure	Square with Extrusion	29	102	102	1.77	Yes	1500	Survives with 2J of Energy
Solar Panels	5	FR-4 PCB	Square	13	1.5	82	100	No	-	Demise
Super capacitors	10		Cylinder	X	10	32	-	No	-	Demise
GPS Patch Antenna	1	Ceramic	Box	10	17	17	8.813	Yes	1400	Demise at 73.1km Altitude
GPS Board	1	FR-4 PCB	Square	78	90	96	13	No	-	Demise
Comms. Board	1	FR-4 PCB	Square	127	90	96	13	No	-	Demise
EPS Board	1	FR-4 PCB	Square	76	90	96	13	No	-	Demise
OBC Board	1	FR-4 PCB	Square	96	92	96	13	No	-	Demise
Sep Switches	2	Steel/Plastic		<1	1.7	1.7	-	No	-	Demise
Risers	16	Aluminum 7075	Cylindrical	<1	6	30	-	No	-	Demise
Fasteners	8	Aluminum 7075	Triangular	8	-	-	-	No	-	Demise
Cabling	2ft	Copper Alloy	Wire	<30g	-	-	-	No	-	Demise

Appendix C. ELaNa-XIV Component List by CubeSat: MakerSat-0

Name	Qty	Material	Body Type	Mass (g) (total)	Diameter / Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp	Survivability
MakerSat	1	-	-	-	-	-	-	-	-	-
External Structure	1	Aluminum 6061	Box	550	100	100	100	No	-	Demise
Patch Antenna	3	Ceramic	Board	4	25	25	4.5	No	-	Demise
Solar Panels	5	Fiberglass	Panel	6	80	100	2	No	-	Demise
Sep Switches	2	Steel / Gold	Board	1	6.5	20	10.25	No	-	Demise
PIN Diode Detector	1	Fiberglass / Copper / Gold	Board	5	15	25	7.5	No	-	Demise
Spring Plungers	2	Steel / Stainless Steel	Round	1	3.5	15	-	Yes	1400	Demise
RBF Pin	1	Steel / Stainless Steel	Cylinder	3	2	10	-	Yes	1400	Demise
Batteries	2	Aluminum Foil / Plastic / Lithium	Box	42.5	50	50	17	No	-	Demise
EyeStar Simplex Comm. Board	1	Fiberglass / Copper	Board	33	40	70	8	No	-	Demise
GPS Board	1	Fiberglass / Copper	Board	32	53	53	8	No	-	Demise
Payload Hub Board	1	Fiberglass / Copper	Board	32	90	96	8	No	-	Demise
Polymer Science Board	1	Fiberglass / Copper	Board	32	90	96	8	No	-	Demise
vibration motor and mount	1	Aluminum	Cylinder	100	30	20	20	No	-	Demise
five cantilever mass samples	5	polymer	Square	2	10	20	10	No	-	Demise
TI MSP430 LaunchPad	1	Fiberglass / Copper	Square	20	50	70	8	No	-	Demise
Rad Dose Science board	1	Fiberglass / Copper	Square	32	90	96	8	No	-	Demise
TI MSP430 LaunchPad	1	Fiberglass / Copper	Square	20	50	70	8	No	-	Demise
Fasteners / Spacers	50	Stainless Steel / Aluminum	Cylinder	1	4.9	10	-	Yes	1400	Demise
Cabling	5	Copper alloy	Cylinder	10	Various	Various	-	No	-	Demise
Magnet & Damping	5	Perm Mag, MU-Metal	Sheet	10	10	10	10	Yes	1450	Demise

Appendix D. ELaNa-XIV Component List by CubeSat: MiRaTA

Name	Qty	Material	Body Type	Mass (g)	Diameter/ Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp	Survivability
MiRaTA										
CubeSat Structure	1	Al 6061 / Al 5052	Box	0.604	See below	See below	See below	No	-	Demise
Ram Plate	1	5052-H32 Aluminum	Square	0.044	97	97	1	No	-	Demise
MAI 400 Top Cover	1	6061-T6 Aluminum	Cube	0.102	97	97	1	No	-	Demise
MAI 400 Bottom Cover	1	6061-T6 Aluminum	Square	0.076	97	97	1	No	-	Demise
MAI Sep Switch Bracket	3	6061-T6 Aluminum	Bracket	0.004	5	5	5	No	-	Demise
Side Plate Housing (Left)	1	5052-H32 Aluminum	Rectangle	0.068	97	324	1	No	-	Demise
Side Plate Housing (Right)	1	6061-T6 Aluminum	Rectangle	0.074	97	324	1	No	-	Demise
Housing Front	1	5052-H32 Aluminum	Rectangle	0.096	97	324	1	No	-	Demise
Housing Back	1	5052-H32 Aluminum	Rectangle	0.088	97	324	1	No	-	Demise
Anti-Ram Plate	1	5052-H32 Aluminum	Square	0.038	97	97	1	No	-	Demise
LNA L Bracket	1	6061-T6 Aluminum	Bracket	0.014	59	44	10	No	-	Demise
Antennas	2	CABLE: PTFE dielectric insulator, Silver-plated copper clad steel wire, Tin-soaked copper braid CONNECTORS: Gold plated brass ANTENNA: Mylar-polymer coating on metal blade	Measuring tape	0.010	178	6	0.2		-	Demise
Solar Panels	2	3 faces with solar cells. (no cells on body mounted PCB; cells on 2 Zenith facing PCBs; Cells on 1 Nadir facing PCB)	Rectangular	0.640	152	324	0.8	No	-	Demise
CTAGS	1	TMM 3, RT6002, RO4003C Cu double sided substrates	Rectangular	0.479	82	330	6.5		-	Demise
Radiometer	1	6061-T6 Aluminum and 5052-H32 Aluminum	Box	0.843	80	80	80	No	-	Demise
Sep Switches	3	Thermoplastic, thermoplastic acetal, silver plated commercial bronze, beryllium copper, stainless steel, fine silver, cold rolled steel nickel-plated	Switch	0.005	5	20	10	No	-	Demise
Radar Tag	1	TBD	Rectangle	0.075	83	100	1.7	No	-	Demise

Name	Qty	Material	Body Type	Mass (g)	Diameter/ Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp	Survivability
Batteries	1 pack of 4 cells	BOARDS: Araldite 2014 epoxy, 1B31 Acrylic conformal coating, Dow Corning 6-1104 adhesive, Stycast 4952 thermally conducting RTV, FR4 PCBs, CARAPACE EMP110 or XV501T-4 solder resist, Sn62 or Sn62 (Tin/Lead) solder, Alpa Rosin Flux (RF800 ROL 0) SEALED BATT	Cube	0.200	90	96	14.4	No	-	Demise
ADCS Components	1	STRUCTURE: Aluminum (MIL-DTL-5541F, Type I or II, class 1A), Hard anodized aluminum (MIL-A8625F, Type III, class 1), Stainless steel 18-8 screws and standoffs, Arathane 5753 A/B ; WIRES: MIL-W-16878/4 TFE WHEELS: Maxon EC-9, Braycote 601 EF, Ceramic ball	Cube	0.79	99	99	50	No	-	Demise
L3Com UHF Cadet Radio	1	SAMTEC ESQ-126-39-G-D stackthrough CONNECTORS: 3.22g Liquid Crystal Polymer, 0.91g Polybutylene Terephtalate, 4.03g Phosphor Bronze, 0.04g Nickel, 0.01g Gold BOARDS: Baked-out FR4 CAPACITORS: Ceramic STAKING EPOXY: Arathane 5753 A/B (LV) HOUSING: Aluminum	Square	0.086	90	96	15.5	No	-	Demise
EPS Board	1	BOARDS: Araldite 2014 epoxy, 1B31 Acrylic conformal coating, Dow Corning 6-1104 adhesive, Stycast 4952 thermally conducting RTV, FR4 PCBs, CARAPACE EMP110 or XV501T-4 solder resist, Sn62 or Sn62 (Tin/Lead) solder, Alpa Rosin Flux (RF800 ROL 0) CONNECTORS:	Square	0.140	90	96	13.2	No	-	Demise
Motherboard	1	PCB FR-4, various Samtec connectors, headers, circuit board components.	Square	0.074	90	96	13.2	No	-	Demise
Fasteners/Screws	TBD	Stainless Steel	Screws	0.25	Varied	Varied	Varied	Yes	1500	Demise at 77.9km Altitude
Cabling	TBD	RG405 Coax (copper clad steel, silver); 24AWG wire, type M22759/11-24 (silver coated copper with polyetrafluoroethylene [PTFE] insulation)	Cables	0.15	Varied	Varied	Varied	No	-	Demise

Appendix E. ELaNa-XIV Component List by CubeSat: RadFXSat

Name	Qty	Material	Body Type	Mass (g)	Diameter/ Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp	Survivability
RadFXSat			box (1U)							
CubeSat Walls	2	Aluminum 5052 H32	sheet w/ bends	32.	200.	108.	1.	No	-	Demise
Solar Panels (+Z, -Z)	2	Fiberglass	sheet	42.	97.	97.	1.6	No	-	Demise
Solar Panels (+X, -X, +Y, -Y)	4	Fiberglass	sheet	43.	81.	108.	1.6	No	-	Demise
Rail Ends	8	Aluminum 6061	stepped box	4.	21.	21.	10.	No	-	Demise
Antenna	1	Beryllium Copper	wire	1.	0.5	165.	-	No	-	Demise
Antenna	1	Beryllium Copper	wire	1.	0.5	530.	-	No	-	Demise
Antennae Posts	2	Copper	cylinder	1.	5.	4.	-	No	-	Demise
Antennae Posts	2	Fiberglass	cylinder	1.	5.	4.	-	No	-	Demise
Antennae Posts	4	Delrin	cylinder	1.	5.	4.	-	No	-	Demise
PCB Stack mounts	8	Delrin	box	1.	14.	14.	7.	No	-	Demise
PCB Stack screws	4	stainless steel	cylinder	1.3	2.8	98.		Yes	1500	Demise at 77.6km Altitude
VUC PCB	1	Fiberglass	sheet	38.	95.	95.	1.6	No	-	Demise
LEP PCB	3	Fiberglass	sheet	38.	95.	95.	1.6	No	-	Demise
Batteries	6	NiCad "A" battery	cylinder	31.	17.	49.	-	No	-	Demise
Hysteresis Rods	2	Permalloy	cylinder	4.8	3.2	70.	-	No	-	Demise
Battery PCB (excl Batt,Hyst,Tan)	1	Fiberglass	sheet	50.	95.	95.	1.6	No	-	Demise
PSU PCB (excl Lead,Tan)	1	Fiberglass	sheet	49.	95.	95.	1.6	No	-	Demise
IHU PCB (excl Tan)	1	Fiberglass	sheet	46.	95.	95.	1.6	No	-	Demise
RX PCB (pop excl RF Shield)	1	Fiberglass	sheet	48.	95.	95.	1.6	No	-	Demise
TX PCB (pop excl RF Shield,Tan)	1	Fiberglass	sheet	44.	95.	95.	1.6	No	-	Demise
RF Shields	2	Copper	sheet	18.	80.	80.	0.5	No	-	Demise
PCB Standoffs	20	Aluminum 6061	hollow cylinder	0.5	6.4	8.2	-	No	-	Demise
PCB Standoffs	8	Copper	hollow cylinder	0.8	4.8	8.2	-	No	-	Demise
PCB Standoffs	8	Delrin	hollow cylinder	0.3	6.4	8.2	-	No	-	Demise
Magnet	1	Neodymium	cylinder	5.3	6.4	19.		Yes	1300	Demise at 77.8km Altitude
Fasteners, cabling, misc	1	varies	-	33.	-	-	-	No	-	Demise

Name	Qty	Material	Body Type	Mass (g)	Diameter/ Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp	Survivability
Lead ballast	1	Lead	sheet	220.	95.	65.3	3.1	No	-	Demise
Tantalum radiation shield	2	Tantalum	sheet	3.6	9.	24.	1.	Yes	2980	Survives to the Ground with 2J of Energy
Tantalum radiation shield	1	Tantalum	sheet	2.3	9.	15.	1.	Yes	2980	Survives to the Ground with 1J of Energy
Tantalum radiation shield	1	Tantalum	sheet	1.9	15.	15.	0.5	Yes	2980	Survives to the ground with < 1J of energy
Tantalum radiation shield	2	Tantalum	sheet	1.1	9.	15.	0.5	Yes	2980	Survives to the ground with < 1J of energy
Tantalum radiation shield	4	Tantalum	sheet	0.8	5.	10.	1.	Yes	2980	Survives to the ground with < 1J of energy
Tantalum radiation shield	4	Tantalum	sheet	0.8	6.	8.	1.	Yes	2980	Survives to the ground with < 1J of energy
Tantalum radiation shield	1	Tantalum	sheet	0.8	6.	15.	0.5	Yes	2980	Survives to the ground with < 1J of energy
Tantalum radiation shield	1	Tantalum	sheet	0.7	9.	9.	0.5	Yes	2980	Survives to the ground with < 1J of energy
Tantalum radiation shield	2	Tantalum	sheet	0.6	6.	6.	1.	Yes	2980	Survives to the ground with < 1J of energy
Tantalum radiation shield	1	Tantalum	sheet	0.3	6.	6.	0.5	Yes	2980	Survives to the ground with < 1J of energy
Tantalum radiation shield	2	Tantalum	sheet	0.1	3.5	3.5	0.5	Yes	2980	Survives to the ground with < 1J of energy

Appendix F. ELaNa-XIV Component List by CubeSat: DAVE (Back Up)

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

*Tungsten Crystalline Powder Modeled as 200 x 1g spheres of tungsten