ELVL-2018-0045490 Rev B
February 13, 2020

Orbital Debris Assessment for the NEUTRON-1 CubeSat per NASA-STD 8719.14A

Signature Page

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Reply to Attn of: VA-H1

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

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

SUBJECT: Orbital Debris Assessment Report (ODAR) for the NEUTRON-1 CubeSat

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. International Space Station Reference Trajectory, delivered May 2017
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
I. HQ OSMA Email:6U CubeSat Battery Non Passivation Suzanne Aleman to Justin Treptow, 8 August 2017

The intent of this report is to satisfy the orbital debris requirements listed in ref. (a) for the NEUTRON-1 CubeSat, which will be deployed from the International Space Station. 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.

RECORD OF REVISIONS		
REV	**DESCRIPTION**	**DATE**
0	Original submission	February 2019
A	Corrected typographical errors in original	April 2019
B	Updated launch vehicle, CONOPS, CubeSat mass properties and component sheet	February 2020

The following table summarizes the compliance status of the NEUTRON-1 CubeSat to be launched as part of the ELaNa-31 complement. NEUTRON-1 is fully compliant with all applicable requirements.

Table 1: Orbital Debris Requirement Compliance Matrix

Requirement	Compliance Assessment	Comments
4.3-1a	Not applicable	No planned debris release
4.3-1b	Not applicable	No planned debris release
4.3-2	Not applicable	No planned debris release
4.4-1	Compliant	On board energy source (batteries) incapable of debris-producing failure
4.4-2	Compliant	On board energy source (batteries) incapable of debris-producing failure
4.4-3	Not applicable	No planned breakups
4.4-4	Not applicable	No planned breakups
4.5-1	Compliant	
4.5-2	Not applicable	
4.6-1(a)	Compliant	Worst case lifetime 1.27 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 for NEUTRON-1

Section 1: Program Management and Mission Overview

NEUTRON-1 is sponsored by the Human Exploration and Operations Mission Directorate at NASA Headquarters. The Program Executive is John Guidi. Responsible program/project manager and senior scientific and management personnel are as follows:

NEUTRON-1: Lloyd French, University of Hawaii at Manoa, - Project Manager
Dr. Peter Engler, University of Hawaii at Manoa, Principal Investigator

Program Milestone Schedule	
Task	Date
CubeSat Selection	October 30th, 2018
Delivery to Nanoracks	June 2020
Launch	NET August 2020

Figure 1: Program Milestone Schedule

NEUTRON-1 will be launched as a payload on the Antares launch vehicle executing the NG-14 mission. NEUTRON-1 will be deployed from the ISS. NEUTRON is identified in Table 2.

NEUTRON-1 weighs approximately 3.6 kg.

Section 2: Spacecraft Description

Table 2 outlines the generic attributes of the spacecraft.

Table 2: NEUTRON-1 Attributes

CubeSat Names	CubeSat Quantity	CubeSat size (mm^3)	CubeSat Masses (kg)
NEUTRON-1	1	340 x 100 x 100	3.6

The following pages describe the NEUTRON-1 CubeSat.

NEUTRON-1 – University of Hawaii – 3U

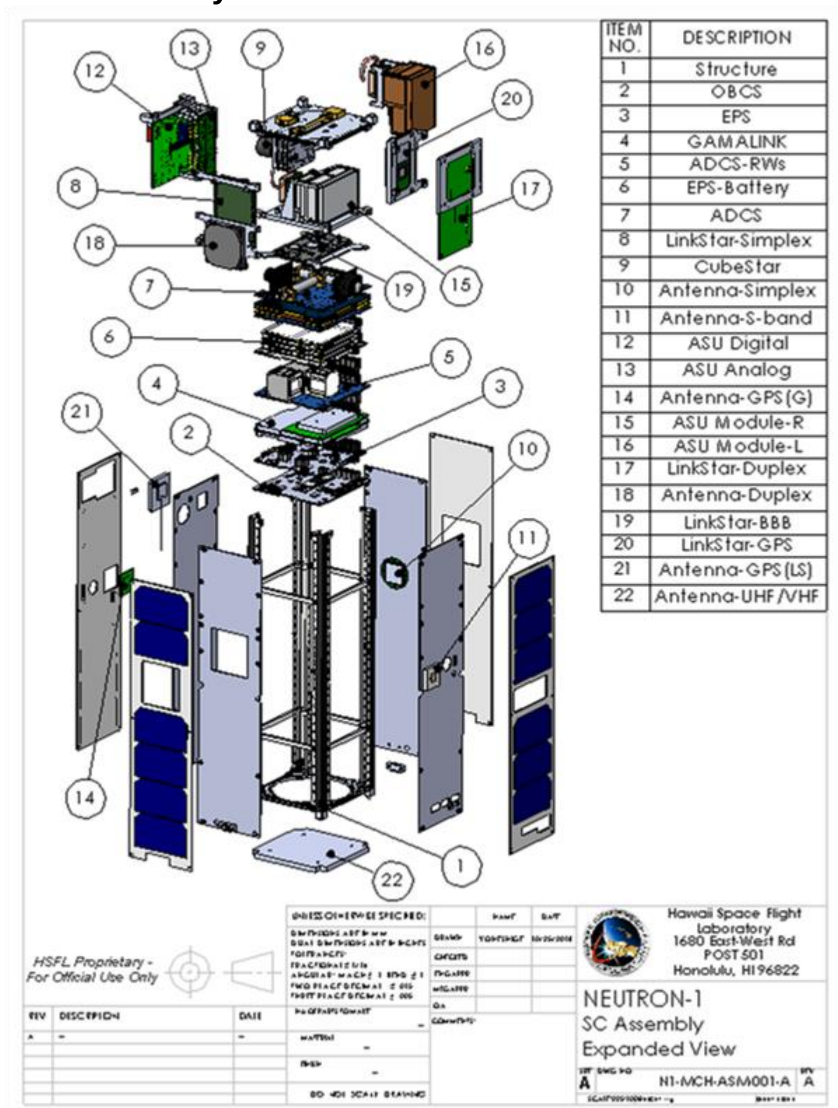

Figure 2: NEUTRON-1 exploded view

Overview

NEUTRON-1 will perform science and technology investigations: Neutron detection, COSMOS flight software operations, and COTS ADCS validation. The science investigation uses an ASU neutron detector to investigate global neutron counts. The instrument operation is also a flight verification and validation of the instrument payload for the LunaH-Map mission. The COSMOS operations investigation will explore unique integrated software tools for coordinated mission commanding, data management, and ground operations. The COTS ADCS investigation will verify vendor specifications during flight with respect to the pointing accuracy, pointing knowledge, and attitude jitter.

CONOPS

Upon release, after a 45 min delay, the UHF/VHF antennas will be deployed. Neutron-1 will power up spacecraft systems, perform orbital checkout, begin beaconing GPS and time data via the GlobalStar network, and the ADCS will begin detumble operation. After the first few orbits, and contact has been established via the GlobalStar network, the OBCS will perform COSMOS Operations and the ADCS will perform orientation control maneuvers by performing pointing, slew, and tracking commands. Once healthy operation is established, science data collection operation will be conducted, and science data will be downlinked via the GlobalStar network. The UHF/VHF radio will serve as an amateur radio transponder service. After the science mission, the satellite will be turned over for amateur activities.

During the first 6 months of operation, HSFL will operate the satellite as above, under an Experimental license. Also, during this phase, the CubeSat will host a UHF/VHF radio which will be operated by the Kauai Community College Amateur Radio Club (KCC), as an amateur transponder service.

After 6 months of operation, HSFL will transfer ownership of the CubeSat to KCC, and KCC will take over operation of the satellite as an amateur activity.

Materials

The primary CubeSat structure is made of an Aluminum 6082-T6 frame with titanium structural rods. The 3U CubeSat contains standard commercial off the shelf (COTS) electrical components, PCBs, materials, solar cells, and an in-house designed and built OBC. The solar panels are multi junction solar cells with cover glass using standard silicone adhesives upon G-10 substrate. The circuit board components are encapsulated with conformal coatings for protection.

Hazards

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

Batteries

The electrical power system consists of a ClydeSpace 3rd Generation 3U EPS and a ClydeSpace 40Whr CubeSat battery, containing two lithium polymer pouch cells. The battery features over-current and under-voltage protections, multiple high-side and low-side solid-state inhibits, as well as voltage, current and temperature telemetries to monitor battery operation. The cells are qualified to NASA standards EP-Wi-032. The battery cells are UL recognized component according to UL 1642.

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 for NEUTRON-1, 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 NEUTRON-1 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))

Limitations in space and mass prevent the inclusion of the necessary resources to disconnect the battery or the solar arrays at EOM. However, the low charges and small battery cells on the CubeSat's power system prevents a catastrophic failure, so that passivation at EOM is not necessary to prevent an explosion or deflagration large enough to release orbital debris.

Assessment of spacecraft compliance with Requirements 4.4-1 through 4.4-4 shows that with a maximum CubeSat lifetime of 1.27 years maximum, NEUTRON-1 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.

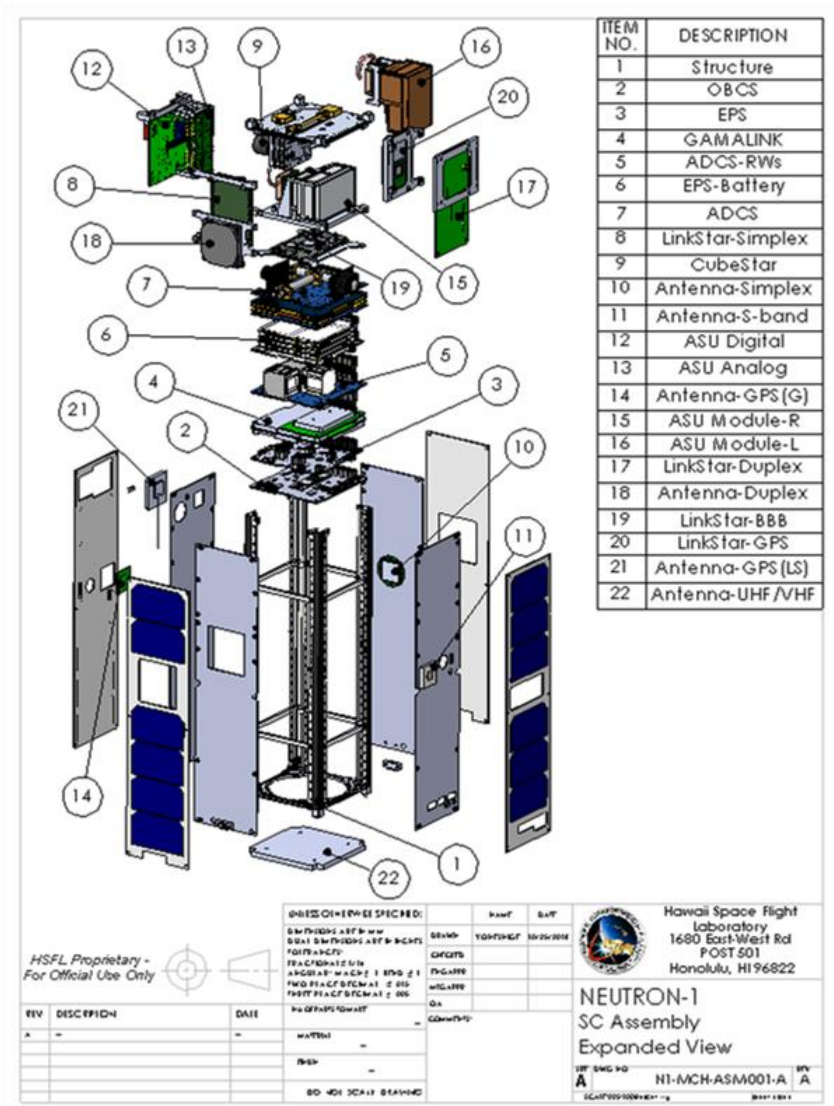

Figure 4: NEUTRON-1 Expanded View

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

Equation 1: Mean Cross Sectional Area for Convex Objects

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

Equation 2: Mean Cross Sectional Area for Complex Objects

The CubeSat evaluated for this ODAR are stowed in a convex configuration, indicating there are no elements of the CubeSat obscuring another element of the same CubeSat from view. Thus, the mean CSA for the stowed CubeSat was calculated using Equation 1. This configuration renders the longest orbital life times for all CubeSat.

Once a CubeSat has been ejected from the CubeSat dispenser 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 NEUTRON-1 (~3.6 kg) orbit at deployment will be 424 x 410 nm at a 51.6˚ inclination. With an area to mass ratio of 0.008 m^2/kg, DAS yields 1.27 years for orbit lifetime for its stowed state, which in turn is used to obtain the collision probability. NEUTRON-1 is calculated to have a probability of collision of 0.0. Table 3 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.

CubeSat		NEUTRON-1
	Mass (kg)	3.593
Stowed	Mean C/S Area (m^2)	0.027
Stowed	Area-to Mass (m^2/kg)	0.008
Stowed	Orbital Lifetime (yrs)	**1.27**
Stowed	Probability of collision (10^X)	**0.0000**
Deployed	Mean C/S Area (m^2)	0.037
Deployed	Area-to Mass (m^2/kg)	0.102
Deployed	Orbital Lifetime (yrs)	**0.263**
Deployed	Probability of collision (10^X)	**0.0000**

Solar Flux Table Dated 1/16/2020

Table 3: CubeSat Orbital Lifetime & Collision Probability

The probability of NEUTRON-1 colliding 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.

NEUTRON-1 has no capability nor have plans for end-of-mission disposal, therefore requirement 4.5-2 is not applicable.

Assessment of spacecraft compliance with Requirements 4.5-1 shows NEUTRON-1 to be compliant. Requirement 4.5-2 is not applicable to this mission.

Section 6: Assessment of Spacecraft Postmission Disposal Plans and Procedures

NEUTRON-1 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 (smallest Area-to-Mass) post-mission disposal among the CubeSats finds NEUTRON-1 in its stowed configuration as the worst case. The area-to-mass is calculated for is as follows:

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

Equation 3: Area to Mass

$$\frac{0.027\ m^2}{3.59\ kg} = 0.008\,\frac{m^2}{kg}$$

The assessment of the spacecraft illustrates they are compliant with Requirements 4.6-1 through 4.6-5.

<u>DAS 2.1.1 Orbital Lifetime Calculations:</u>
DAS inputs are: 424.5 km maximum apogee 409.8 km maximum perigee altitudes with an inclination of 51.6º at deployment no earlier than August 2020. An area to mass ratio of ~0.008 m^2/kg for the NEUTRON-1 CubeSat was used. DAS 2.1.1 yields a 1.27 years orbit lifetime for NEUTRON-1 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 of NEUTRON-1 was performed. The assessment used DAS 2.1.1, 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 possess the same negligible risk as stainless steel components.

Table 4: NEUTRON-1 High Melting Temperature Material Analysis

Name	Material	Total Mass (kg)	Demise Alt (km)	Kinetic Energy (J)
Circlip	Stainless Steel	.00002	76.8	-
Deployment Compression Spring	Stainless Steel	.00002	77.8	-
Deployment Plunger Pin	Stainless Steel 316L	.00102	77.1	-
Separation Spring	Stainless Steel 316L	.00142	76.5	-
Cross Recessed Screw	Stainless Steel	.00064	76.5	-
Hex Full Nut	Stainless Steel	.00004	77.0	-
CSK Machine Screw	Stainless Steel	.00104	77.0	-
Cap Screw	Stainless Steel	.00608	77.0	-
Payload Module	Gadolinium	.015	0	0
Threaded Rod	Titanium 6Al-4V	.040	0	1
18-8 Stainless Steel fasteners	18-8 Stainless Steel	.010	77.0	-
Stainless Steel 304 A2 Fasteners	Stainless Steel 304	.010	76.5	-
Stainless Steel 316 A4 Fasteners	Stainless Steel 316	.010	77.0	-

The majority of stainless steel components demise upon reentry and NEUTRON-1 with the 1:10,000 probability of Human Casualty Requirement 4.7-1. A breakdown of the determined probabilities follows:

Table 5: Requirement 4.7-1 Compliance for NEUTRON-1

Name	Status	Risk of Human Casualty
NEUTRON-1	Compliant	1:0

*Requirement 4.7-1 Probability of Human Casualty > 1:10,000

If a component survives to the ground but has less than 15 Joules of kinetic energy, it is not included in the Debris Casualty Area that inputs into the Probability of Human Casualty calculation. This is why NEUTRON-1 has a 1:0 probability as none of its components have more than 15J of energy.

NEUTRON-1 is shown to be in compliance with Requirement 4.7-1 of NASA-STD-8719.14A.

Section 8: Assessment for Tether Missions

NEUTRON-1 will not be deploying any tethers.

NEUTRON-1 satisfies Section 8’s requirement 4.8-1.

Section 9-14

ODAR sections 9 through 14 pertain to the launch vehicle, and are not covered here. Launch vehicle sections of the ODAR are the responsibility of the CRS provider.

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

/original signed by/

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Flight Design Analyst
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cc: VA-H/Mr. Carney
VA-H1/Mr. Beaver
VA-H1/Mr. Haddox
VA-C/Mr. Higginbotham
VA-C/Mrs. Nufer
SA-D2/Mr. Frattin
SA-D2/Mr. Hale
SA-D2/Mr. Henry
Analex-3/Mr. Davis
Analex-22/Ms. Ramos

Appendix Index:

Appendix A. NEUTRON-1 Component List

Item Number	Name	Qty	Material	Body Type	Mass (g) (total)	Diameter / Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp (F°)	Survivability
1	Neutron-1	1		3U Box	3593.5 6	-	-	-	No	-	Demise
2	*UPDATED* Clydespace 3U CubeSat Structure	1	Al 6082-T6 and Al 6061-T6	Box	604.5	100	340.5	100	No	-	Demise
3	Solar Panel Emcore BTJM Photovoltaic Cells Triple-Junction with Monolithic Diode	24	BTJM InGaP/InGaAs/Ge	Rectangle	53.52	39.7	69.1	0.5	No	-	Demise
4	*ADDED* Solar Panel PCBs	4	PCB	Rectangle	324	82	313.5	1.5	No	-	Demise
5	*UPDATED* ISISpace UHF/VHF Antenna	1	Aluminum and PCB	Box	90	98	98	7	No	-	Demise
6	*UPDATED* S-Band Patch Antenna	1	Ceramic	Box	15.6	25	25	4.84	No	-	Demise
7	*UPDATED* Disconnected GPS Patch Antenna	1	Ceramic	Box	8	18	18	6.8	No	-	Demise
8	*UPDATED* NovAtel Taoglas GPS Antenna	1	Ceramic	Box	11	35	35	6.9	No	-	Demise
9	*UPDATED* GlobalStar Duplex Patch Antenna	1	Ceramic	Box	82	48.41	48.41	9.66	No	-	Demise
10	CubeSpace ADCS Deployable Magnetometer	1	Alodined Aluminum and PTFE harness	Box	15	17.2	83.3	6.7	No	-	Demise
11	CubeSpace ADCS Static Magnetometer	1	Alodined Aluminum and PTFE harness	Box	4	16.8	23.2	6.3	No	-	Demise
12	CubeSpace Coarse Sun Sensors and Harness	10	Photodiode, TFE, Teflon, LCP	Rectangle	15	3.8	10.8	1.6	No	-	Demise
13	Circlip E-Type 1.5mm	2	Stainless Steel	Disk	0.02	1.5	0.4	N/A	No	-	Demise
14	Plastic Bearing	2	iglidur® X	Cylinder	0.06	3.5	3	N/A	No	-	Demise
15	Deployment Compression Spring	2	Stainless Steel	Spring	0.02	0.6	5	0.25	Yes	-	Demise
16	Deployment Plunger Pin	2	Stainless Steel 316L	Pin	1.02	3	16	N/A	Yes	-	Demise
17	Deployment Switch Mount	4	Aluminium Al 6082-T6	Box	0.28	5	7	1.5	No	-	Demise
18	Separation Spring	2	Stainless Steel 316L	Spring	1.42	2	7	0.2	Yes	-	Demise

19	M1.7 x 6 Cross Recessed Screw	8	Stainless Steel A2	Screw	0.64	1.7	6	N/A	Yes	-	Demise
20	M1.7 Hex Full Nut	8	Stainless Steel A4	Nut	0.4	4	1.5	N/A	Yes	-	Demise
21	M2 x 6 TX6 CSK Machine Screw	8	Stainless Steel A4	Screw	1.04	2	6	N/A	Yes	-	Demise
22	M2.5 x 4 Ultra Low Head Hex Cap Screw	32	Stainless Steel A2	Screw	6.08	2.5	4	N/A	Yes	-	Demise
23	*UPDATED* Flight Computer Board	1	PCB	PC104 form factor	89	96	90	14	No	-	Demise
24	*UPDATED* ClydeSpace 3rd Generation 3U EPS	1	PCB	PC104 form factor	93	96	90	13.5	No	-	Demise
25	*UPDATED* ClydeSpace 40Whr CubeSat Battery Board	1	PCB	PC104 form factor	65	96	90	5.6	No	-	Demise
26	*UPDATED* ClydeSpace 40Whr CubeSat Battery Cell Pack	1	Lithium ion polymer cells	Box	270.5	96	90	20	No	-	Demise
27	*UPDATED* CubeSpace ADCS PC104 PCB	4	PCB	PC104 form factor	240	96	90	10	No	-	Demise
28	*UPDATED* CubeSpace ADCS Reaction Wheels	3	Brass with TBC (Possibly ABS)	Box	189.9	28	31	26	No	-	Demise
29	*UPDATED* CubeSpace ADCS Magnetic Coil	1	Aluminum and Enamel coated wire	Square	46	96	90	8	No	-	Demise
30	*UPDATED* CubeSpace ADCS Magnetorquers	2	Alodined Aluminum, PVDF Kynar	Rod	53.4	18	61	17	No	-	Demise
31	CubeSpace Nadir and Sun Sensor Cameras	2	Glass and Aluminum Lenses and ABS holder	Lens	25.4	31	40	19	No	-	Demise
32	CubeSpace Star Tracker	1	Aluminum and Glass	Lens	66	35	50	55	No	-	Demise
33	*ADDED* ISISpace UHF/VHF Radio	1	PCB and Aluminum shielding	Board	75	90	96	15	No	-	Demise
34	NovAtel OEM719 GPS Board	1	PCB	Board	31	46	71	11	No	-	Demise
35	LinkStar GSP1720 Duplex Radio	1	PCB	Board	60	61	118.7	3.6	No	-	Demise
36	*UPDATED* BeagleBone Black	1	PCB	Board	38.9	54.7	86.4	8	No	-	Demise
37	*UPDATED* Payload Digital Data Acquistion Board	1	PCB FR4, Conathane EN11/EN4 Coating	Board	48.84	75	82	10	No	-	Demise
38	*UPDATED* Payload Analog Board Sensor Interface	1	PCB FR4, Conathane EN11/EN4 Coating	Board	75.32	32	75	20	No	-	Demise

39	*UPDATED* Payload Module Enclosure	1	Aluminum 7075-T7351 with clear chemfilm finish	Boot	42.22	45.2	68.2	38.7	No	-	Demise
40	Payload Enclosure CLYC Scintillator	1	Cs2LiYCl6	Box	167.83	-	-	-	No	-	Demise
41	Payload Module Photomultiplier Tube R11265-100	1	Hamamatsu R11265-100 Photomultiplier Tube	Box	25	26.2	26.2	17.8	No	-	Demise
42	Payload Module Voltage Divider Network PCB	1	PCB FR4	Board	4	30	30	6.3	No	-	Demise
43	*UPDATED* Payload Module Gadolinium	1	Gadolinium	Sheet	15	42	51	0.5	Yes	-	Demise
44	*ADDED* CubeStar Mounting Bracket	1	Al 6061-T6	Bracket	8.8	-	-	-	No	-	Demise
45	*ADDED* Coarse Sun Sensor Mounting Bracket	2	Al 6061-T6	Bracket	3.2	-	-	-	No	-	Demise
46	*ADDED* LinkStar Duplex Mounting Bracket	1	Al 6061-T6	Bracket	17.1	-	-	-	No	-	Demise
47	*ADDED* BeagleBone Black Mounting Bracket	1	Al 6061-T6	Bracket	29	-	-	-	No	-	Demise
48	*ADDED* LinkStar Duplex Antenna Mounting Bracket	1	Al 6061-T6	Bracket	15.28	-	-	-	No	-	Demise
49	*ADDED* LinkStar Duplex Support Mounting Bracket	1	Al 6061-T6	Bracket	18.1	-	-	-	No	-	Demise
50	*ADDED* NovAtel GPS Mounting Bracket	1	Al 6061-T6	Bracket	19.7	-	-	-	No	-	Demise
51	*ADDED* Payload Interboard-A Mounting Bracket	1	Al 6061-T6	Bracket	10.39	-	-	-	No	-	Demise
52	*ADDED* Payload-Linkstar Mounting Bracket	1	Al 6061-T6	Bracket	35.8	-	-	-	No	-	Demise
53	*ADDED* Payload Board Adapter-A Mounting Bracket	1	Al 6061-T6	Bracket	1.14	-	-	-	No	-	Demise
54	*ADDED* Payload Interboard-B Mounting Bracket	1	Al 6061-T6	Bracket	10.6	-	-	-	No	-	Demise
55	*ADDED* Payload Board Mounting Bracket	1	Al 6061-T6	Bracket	8.79	-	-	-	No	-	Demise
56	*ADDED* Payload Board Adapter-B Mounting Bracket	1	Al 6061-T6	Bracket	1.74	-	-	-	No	-	Demise
57	*ADDED* Payload Back Support Mounting Bracket	1	Al 6061-T6	Bracket	10.26	-	-	-	No	-	Demise
58	*ADDED* Payload-Duplex Mounting Bracket	1	Al 6061-T6	Bracket	0.9	-	-	-	No	-	Demise

59	*ADDED* Payload Module Top-A Mounting Bracket	1	Al 6061-T6	Bracket	4	-	-	-	No	-	Demise
60	*ADDED* Payload Module Top-B Mounting Bracket	1	Al 6061-T6	Bracket	4	-	-	-	No	-	Demise
61	*UPDATED* Payload Enclosure Silicone Pad	1	Bisco BF1000 Silicone Foam	Box	0.45	-	-	-	No	-	Demise
62	*UPDATED* Payload Enclosure Optical Pad	1	Polydimethylsiloxane (PDMS) EJ-560 is BC-634A Equivalent material	Box	1.68	-	-	-	No	-	Demise
63	*UPDATED* Payload Enclosure Window	1	Quartz	Plate	4.13	35	35	1.4	No	-	Demise
64	Payload Enclosure Epoxy Window Seal	1	3M 1838		2	-	-	-	No	-	Demise
65	*UPDATED* Payload Enclosure Epoxy Lid Seal	1	Ablestik 285/Cat 11		3	-	-	-	No	-	Demise
66	*UPDATED* Payload Module PMT Optical Pad	1	Polydimethylsiloxane (PDMS) EJ-560 is BC-634A Equivalent material		0.86	-	-	-	No	-	Demise
67	*UPDATED* Payload High Voltage Copper Foil	1	110 ETP Copper covered with Conathane EN11/EN4 Coating	Foil	2.28	-	-	-	No	-	Demise
68	*UPDATED* Payload Module PMT Socket	1	Polyphenylene Sulfide (PPS) Designation:TECHTRON™ PPS	Connector	2.84	-	-	-	No	-	Demise
69	Payload Module PTFE Alignment	1	Expanded PTFE Gore Gasket		0.2	-	-	-	No	-	Demise
70	*UPDATED* Payload Enclosure Reflector	1	Expanded PTFE Gore Gasket		4.54	-	-	-	No	-	Demise
71	*ADDED* Thermal Gap Fill	1	Chomerics G579		1				No	-	Demise
72	CSK Stack Header Connectors	22	Liquid Crystal Polymer (LCP)	Stack Connector	176	5	66.5	11	No	-	Demise
73	CSK Header Connector Pins	1144	Gold Finished Phosphor Bronze	Pin	80.08	-	-	-	No	-	Demise
74	Threaded Rod	4	Titanium Ti-6Al-4V	Rod	40	3	320.5	N/A	Yes	-	Demise
75	*UPDATED* Fasteners and Inserts	100	Stainless Steel 18-8 Mil. Spec.	Screw	10	-	-	-	Yes	-	Demise
76	*UPDATED* Fasteners and Inserts	100	Stainless Steel 304, SS A2	Screw	10	-	-	-	Yes	-	Demise
77	*UPDATED* Fasteners and Inserts	100	Stainless Steel 316, SS A4	Screw	10	-	-	-	Yes	-	Demise

78	*UPDATED* Cabling/Wiring	100	Copper/silver alloy and insulation	Wire	50	-	-	-	No	-	Demise
79	*ADDED* Thermal Strap for Payload Board FPGA	1	110 Copper	Bent Plate	3.65	-	-	-	No	-	Demise
80	*ADDED* Thermal Strap for Payload Board Processor	1	110 Copper	Bent Plate	5.64	-	-	-	No	-	Demise
81	*ADDED* Thermal Strap for OBC Gumstick	1	110 Copper	Bent Plate	16.43	-	-	-	No	-	Demise
82	*ADDED* Thermal Strap for Beagle Bone Black Processor 1	1	110 Copper	Bent Plate	0.9	-	-	-	No	-	Demise
83	*ADDED* Thermal Strap for Beagle Bone Black Processor 2	1	110 Copper	Bent Plate	5.38	-	-	-	No	-	Demise
84	*ADDED* Thermal Strap for LinkStar Duplex Processors	1	110 Copper	Bent Plate	8.79	-	-	-	No	-	Demise