ELVL-2018-0045468 Rev B
April 16, 2019

Orbital Debris Assessment for The RFTSat CubeSat per NASA-STD 8719.14A

Signature Page

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ELVL-2018-0045468 Rev B

Reply to Attn of: VA-H1

April 16, 2019

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 RFTSat 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. 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 RFTSat mission launching on a Falcon 9 vehicle. RFTSat is the only CubeSat in the ELaNa-27 complement. This report 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	Nov 2018
A	Updated mass properties and component list	April 2019
B	Updated mass properties and CONOPS	April 2019

The following table summarizes the compliance status of the RFTSat payload mission to be flown on the Falcon 9 vehicle. RFTSat is the only CubeSat in the ELaNa-27 complement. The RFTSat mission is fully compliant with all applicable requirements.

Table 1: Orbital Debris Requirement Compliance Matrix

Requirement	Compliance Assessment	Comments
4.3-1a	Not applicable	No planned debris release
4.3-1b	Not applicable	No planned debris release
4.3-2	Not applicable	No planned debris release
4.4-1	Compliant	On board energy source (batteries) incapable of debris-producing failure
4.4-2	Compliant	On board energy source (batteries) incapable of debris-producing failure
4.4-3	Not applicable	No planned breakups
4.4-4	Not applicable	No planned breakups
4.5-1	Compliant	
4.5-2	Not applicable	
4.6-1(a)	Compliant	Worst case lifetime ~3.9 years
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 RFTSat

Section 1: Program Management and Mission Overview

The RFTSat mission 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:

RFTSat: Dr. Joshua Griffin, Principal Investigator, Northwest Nazarene University

Program Milestone Schedule	
Task	**Date**
CubeSat Selection	February 17th, 2017
Delivery to SEOPS	May 6th, 2019
Launch	July 8th, 2019
Deployment	Late July, 2019

Figure 1: Program Milestone Schedule

The RFTSat CubeSat will be launched as a payload on a Falcon 9 launch vehicle executing the SpX-18 cargo mission for the International Space Station. The RFTSat CubeSat will then be deployed by the NG-11 Cygnus vehicle after it departs the International Space Station.

The current launch date is projected to be July 8th, 2019

Section 2: Spacecraft Description

Table 2: outlines its generic attributes.

Table 2: RFTSat

CubeSat Names	CubeSat Quantity	CubeSat size (mm^3)	CubeSat Masses (kg)
RFTSat	1	340.5 x 100 x 100	3.1

The following pages further describe RFTSat.

RFTSat – Northwest Nazarene University – 3U

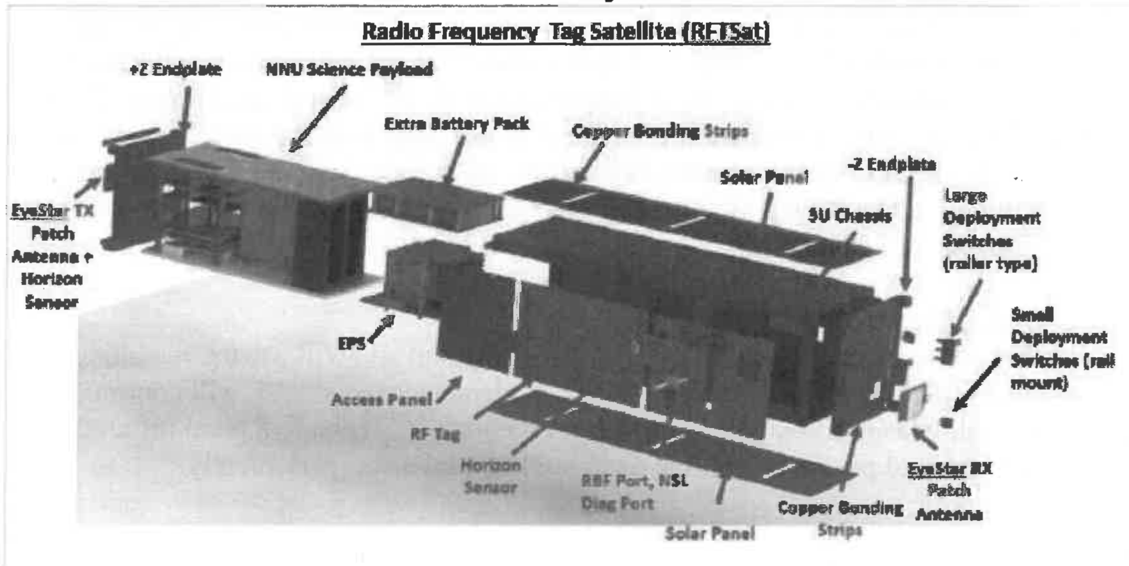

Figure 2: RFTSat Exploded View

Overview

The goal of the Radio Frequency Tag Satellite (RFTSat) mission is to develop and demonstrate the first space-based 5.8GHz RF backscattering communications system. It will allow a wireless passive RF tag to harvest RF energy transmitted through space from an RF reader on the spacecraft, store that energy in a supercapacitor, and power an MCU and various sensors on the tag. Then the collected sensor data will be transmitted back to the reader by modulating this information on the backscattered RF signal. This tag will be mounted at inside the NNU science payload and will be used to measure temperature and, possibly, total-dose radiation. All data will be downlinked to earth via GlobalStar satellite network.

CONOPS

Phase 1: Startup (Day 1)

Upon deployment, RFTSat will power up and start a 30 minute countdown timer. At 30 minutes, the GlobalStar radio will activate and downlink 10 health beacons containing satellite telemetry data. Once the health packets have been sent, the burn wire mechanism will fire (even though the deployable panels have been removed, the firmware is still programmed to fire the burn wires; this should not cause any problems, but we are testing a way to bypass the burn wire fire), power will then be available to the payload; however, payload operations will not start for several orbits to allow the batteries to charge.

Phase 2: Conops (Weeks 1-8)

At this point, the satellite will enter its main conops mode. In the conops, the RF tag reader will be periodically powered (1-3 times every 2 days) and the data collected from the RF tag downlinked via the Eyestar Simplex radio (5-10 times every 2 days). The RF tag data will come from a temperature sensor and, possibly, a total dose ionizing radiation sensor (i.e., RadFET). Satellite health data will be downlinked via the EyeStar radio every 15 minutes. The RF tag system will operate for 8 weeks and will then be shut off by the NSL onboard computer.

Phase 3: NSL Phase (Weeks 9-Re-Entry)

During this phase, NSL will shut down the NNU payload and will use the remainder of the satellite's life to test the longevity of their hardware systems. NSL will continue to transmit satellite health beacons and data from their sensors (two 8x8 pixel infrared horizon sensors and pin diode particle detectors) to Globalstar periodically.

Materials

The RFTSat structure is made of Aluminum 6061-T6 and contains standard commercial-off-the-shelf (COTS) materials, electrical components, PCBs, and solar cells. The GlobalStar radio uses 2 ceramic patch antennas. The uplink frequency is 2.4 GHz and the downlink frequency is 1.6 GHz. The 5.8 GHz RF reader/tag system uses 4 PCB microstrip antennas.

Hazards

There are no pressure vessels, hazardous or exotic materials.

Batteries

The electrical power storage system consists of common lithium-polymer batteries with over-charge/current protection circuitry. The lithium batteries and circuitry are ISS approved with previous flight heritage. The lithium batteries carry the UL-listing number 30156-0.

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.

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 RFTSat, 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 for the RFTSat CubeSat.

The probability of battery explosion is very low, and, due to the very small mass of the satellites and their short orbital lifetimes the effect of an explosion on the far-term LEO environment is negligible (ref (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 3.9 years maximum, the RFTSat 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.

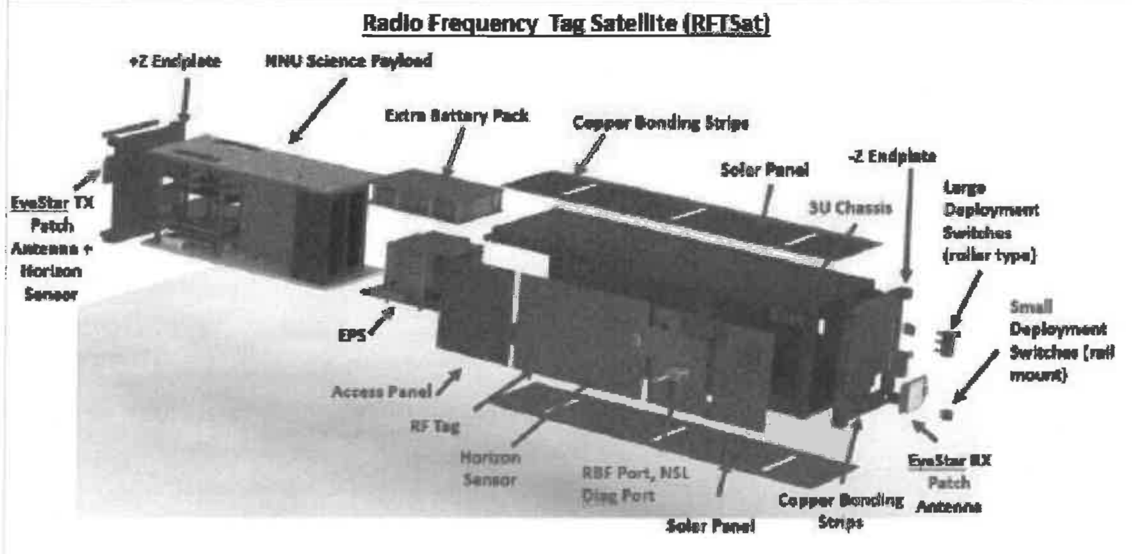

Figure 4: RFTSat Expanded View (with solar panels deployed)

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

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

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 CubeSats.

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 projected orbit altitude is projected to be 500 km. With an area to mass ratio of 0.009 m^2/kg, DAS yields 3.9 years for orbit lifetime at a 500 km orbit altitude, which in turn is used to obtain the collision probability. The RFTSat CubeSat was 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.

	RFTSat	500 nm orbit
	Mass (kg)	3.1
Stowed	Mean C/S Area (m^2)	0.027
Stowed	Area-to Mass (m^2/kg)	0.009
Stowed	Orbital Lifetime (yrs)	**3.9**
Stowed	Probability of collision (10^X)	**0.0000**

Solar Flux Table Dated 12/18/2018

Table 3: CubeSat Orbital Lifetime & Collision Probability

The probability of RFTSat 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.

The CubeSat manifested on this mission have 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 RFTSat to be compliant. Requirement 4.5-2 is not applicable to this mission.

Section 6: Assessment of Spacecraft Postmission Disposal Plans and Procedures

RFTSat 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 WeissSat 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

$$\frac{0.027\ m^2}{3.1\ kg} = 0.009\frac{m^2}{kg}$$

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: 500 km circular altitude with an inclination of 51.6° at deployment no earlier than July 2019. An area to mass ratio of ~0.009 m^2/kg for the RFTSat CubeSat was used. DAS 2.1.1 yields approximately 3.9 years orbital lifetime for RFTSat at a 500 km orbital altitude.

This meets requirement 4.6-1.

Section 7: Assessment of Spacecraft Reentry Hazards

A detailed assessment of the components to be flown on RFTSat 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: RFTSat High Melting Temperature Material Analysis

Name	Material	Total Mass (kg)	Demise Alt (km)	Kinetic Energy (J)
Patch Antenna	Ceramic	.014	77.5	0
Large inhibit switch	Stainless Steel	.002	0	0
Small inhibit switch	Stainless Steel	.0003	0	0
RBF Switches	Stainless Steel		78.0	0
Payload mounting screws	Tantalum	.0003	77.9	0
Bandpass filter housing	Stainless Steel	.012	77.8	0
Mu metal	Stainless Steel	.002	77.8	0
Magnets	Stainless Steel	.002	77.8	0
Low/hi pass filter chip	Stainless Steel	.00002	78.0	0
Large capacitor	Stainless Steel	.003	78.0	0
Small capacitor	Stainless Steel	.0007	77.9	0
Capacitors	Ceramic	.0001	77.9	0
Resistors	Ceramic	.0001	77.9	0
Ceramic Low pass filter	Ceramic	.001	77.8	0
Ceramic bandpass filter	Ceramic	.001	77.6	0
Screws	18-8 Stainless Steel	.00015	0	0
PEM nut	Stainless Steel	.0003	0	0
Washers	Stainles Steel	.0001	76.3	0

The majority of stainless steel components demise upon reentry and the CubeSat complies 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 by CubeSat

Name	Status	Risk of Human Casualty
RFTSat	**Compliant**	**0.00000**

*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 RFTSat CubeSats has a 1:0 probability as none of its components have more than 15J of energy.

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

Section 8: Assessment for Tether Missions

RFTSat will not be deploying any tethers.

RFTSat 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
VA-G2/Mr. Treptow
SA-D2/Mr. Frattin
SA-D2/Mr. Hale
SA-D2/Mr. Henry
Analex-3/Mr. Davis
Analex-22/Ms. Ramos

Appendix Index:

Appendix A. RFTSat 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	Antenna Slot Boards	6	FR4 Multilayer PCB	Square	111.00	83.00	124.60	1.60	No	-	Demise
2	Solar Panels (Chassis)	8	Fiberglass/GaAs	Square	216.00	85.00	110.00	1.60	No	-	Demise
3	Solar Panels (Deployable)	4	Fiberglass/GaAs	Square	116.00	85.00	110.00	1.60	No	-	Demise
4	Chassis	1	Alumimium 6061	Box	735.00	100.00	340.50	100.00	No	-	Demise
5	(+)Z Endplate	1	Alumimium 6061	Square	83.60	100.00	100.00	13.00	No	-	Demise
6	(-)Z Endplate	1	Alumimium 6061	Square	83.60	100.00	100.00	13.00	No	-	Demise
7	Access Panel	5	Alumimium 6061	Square	165.00	83.00	100.00	1.50	No	-	Demise
8	Deployables	2	Fiberglass/FR4/PCB	Rectangle	127.40	82.80	236.70	1.00	No	-	Demise
9	Patch Antennas	2	Ceramic	Square	28.00	25.00	25.00	6.00	Yes	-	Demise
10	Horizon Sensors	2	FR4/Plastic/metal	Square	4.80	25.00	45.00	5.00	No	-	Demise
11	NNU Diagnostic Connectors	1	ZincAlloy/Beryllium Copper/Plastic/Tin/Gold	Rectangle	4.40	12.00	24.00	7.00	No	-	Demise
12	Large Inhibit Switch	2	Stainless Steel / Plastic	Rectangle	4.00	15.00	20.00	6.00	Yes	2500°	0 km
13	Small Inhibit Switch	2	Steel / Plastic	Rectangle	0.60	15.00	20.00	6.00	No	2500°	0 km
14	RBF Switches	2	Steel / Plastic	Rectangle	0.60	8.00	14.00	3.00	Yes	2500°	Demise
15	Burn Wire Board	2	PCB	Square	49.00	83.00	108.00	1.00	No	-	Demise
16	Payload Mounting Screws	8	Stainless Steel	Cylinder	2.41	5.00	0.00	9.00	Yes	2500°	Demise
17	Viton padding	2	Viton	Square	18.00	10.00	160.00	1.00	No	-	Demise
18	EPS/Battery/Radio	1	FR4 Multilayer PCB/Lithium Polymer/Brass/Teflon /Steel/Kapton	Box	268.70	83.65	87.00	48.70	No	-	Demise
19	Extra Battery	1	Lithium Polymer/FR4	Box	224.70	70.00	100.00	20.18	No	-	Demise

20	PLL Board	1	FR4 Multilayer PCB/Rogers 4003C substrate	Square	22.10	55.00	57.00	1.60	No	-	Demise
21	DSP Board	1	FR4 Multilayer PCB	Square	27.10	81.00	87.00	1.60	No	-	Demise
22	Amp/DC Board	1	FR4 Multilayer PCB	Square	25.00	81.00	87.00	1.60	No	-	Demise
23	Motor Board	1	FR4 Multilayer PCB	Square	22.00	82.00	82.00	1.60	No	-	Demise
24	DC/DC Board	1	FR4 Multilayer PCB	Rectangle	16.00	59.00	65.00	1.60	No	-	Demise
25	IB Board	1	FR4 Multilayer PCB	Square	25.00	82.00	87.00	1.60	No	-	Demise
26	CHS Temp Board	1	FR4 Multilayer PCB	Square	40.00	80.00	80.00	1.60	No	-	Demise
27	Tag Board	1	FR4 Multilayer PCB	Rectangle	38.00	124.30	82.60	1.60	No	-	Demise
28	Energy Harvester Board	1	Rogers RO4725 PCB	Rectangle	10.12	92.00	73.00	0.80	No	-	Demise
29	NNU debug port board	1	FR4 Multilayer PCB	Rectangle	4.00	32.00	28.75	1.60	No	-	Demise
30	Bandpass filter housing	1	Stainless Steel	Rectangle	12.00	10.00	48.00	-	Yes	2500°	Demise
31	Reader Antenna Board	1	Rogers 4730 PCB	Rectangle	18.20	80.00	81.00	1.60	No	-	Demise
32	Ladder boards	3	FR4 Mutlilayer PCB	Rectangle	12.00	60.00	20.00	1.60	No	-	Demise
33	Lower Slider	1	Aluminium 6061	Rectangle	152.20	201.02	87.82	4.00	No	-	Demise
34	Upper Slider	1	Aluminium 6061	Rectangle	151.10	201.02	87.82	4.00	No	-	Demise
35	PLL Mount	1	Delrin	Block	12.90	70.00	70.00	7.00	No	-	Demise
36	RBF Switch Mount	1	Aluminium 6061	Block	3.00	12.00	15.00	7.00	No	-	Demise
37	Boom Box	1	Aluminium 6061	Box	250.00	67.00	84.00	36.00	No	-	Demise
38	Mu Metal	6	Nickel-iron alloy	Rectangle	13.50	10.00	60.00	1.00	No	2642°	Demise
39	Magnet	3	Neodymium	Box	6.00	12.00	4.00	4.00	No	-	Demise
40	Low/High pass filter chip	2	Ceramic	Rectangle	0.04	3.20	1.60	1.00	Yes	2520°	Demise
41	RF Cable 1	1	Copper Clad Steel, Silver Plating, PTFE Insulation, FEB Jacket	Cylinder	11.00	2.60	241.00	N/A	No	-	Demise
42	RF Cable 2	1	Copper Clad Steel, Silver Plating, PTFE Insulation, FEB Jacket	Cylinder	14.50	2.60	273.00	N/A	No	-	Demise

43	RF Cable 3	1	Copper Clad Steel, Silver Plating, PTFE Insulation, FEB Jacket	Cylinder	10.50	2.60	90.00	N/A	No	-	Demise
44	RF Cable 4	1	Copper Clad Steel, Silver Plating, PTFE Insulation, FEB Jacket	Cylinder	10.00	2.60	75.00	N/A	No	-	Demise
45	RF SMA Connectors	10	Bodies: Brass, gold plated, Beryllium Copper, PTFE	Box	20.50	6.30	7.00	13.00	No	-	Demise
46	Capacitors	1	Tantalum	Square	3.70	6.00	7.00	5.00	Yes	5463°	Demise
47	Capacitors	1	Tantalum	Square	0.70	4.00	3.00	2.00	Yes	5463°	Demise
48	Capacitors	~250	Ceramic	Square	25.00	2.00	2.00	2.00	Yes	2520°	Demise
49	Resistors	~240	Ceramic	Square	24.00	1.00	1.00	0.50	Yes	2520°	Demise
50	Burn Wire	2	Nylon, Dyneema PE microfiber, Flouropolymer treated microfibers	Cylinder	0.20	0.35	120.00	N/A	No	-	Demise
51	Standoffs	71	Aluminium 6061	Cylinder	48.28	2.00	16.00	N/A	No	-	Demise
52	Thermal Pad	2	Black Carbon/Polysiloxan	Square	26.00	55.00	55.00	2.50	No	-	Demise
53	Ceramic Low Pass Filter	2	Ceramic	Block	2.00	3.20	2.49	1.50	Yes	2520°	Demise
54	Ceramic Bandpass Filter	1	Ceramic	Block	1.00	2.50	2.00	0.90	Yes	2520°	Demise
55	RadFET	1	8-pin ceramic side braze package with kovar lid	Block	0.93	13.20	7.90	2.20	No	-	Demise
56	LocTite		Methacrylate	N/A	-	-	-	-	No	-	Demise
57	Staking Epoxy		3M Scotch Weld 2216	N/A	-	-	-	-	No	-	Demise
58	Conformal Coat		Acrylic Conformal Coat	N/A	-	-	-	-	No	-	Demise
59	Cabling		Phosphor Copper, Tin or Gold Plated		-	-	-	-	No	-	Demise
60	Heat Shrink		FP-301 Polyolefin	Cylinder	-	-	-	-	No	-	Demise
61	Deployable Hinge	4	Nitinol Flatwire	Rectangle	0.40	26.00	3.00	0.15	No	-	Demise
62	Screws	~170	18-8 Stainless Steel	Cylinder	25.50	2.00	7.00	N/A	Yes	2500°	0
63	Spacers	~60	Nylon	Cylinder	1.20	5.00	2.00	N/A	No	-	Demise

64	PEM Nut	6	Stainless Steel	Cylinder	1.80	6.00	3.00	N/A	Yes	2500°	0
65	Misc M2.5/M2 washers and nuts	15	Stainless Steel	Cylinder	1.50	6.00	1.00	N/A	Yes	2500°	Demise