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Orbital Debris Assessment for The SPACE HAUC 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 SPACE HAUC Mission

REFERENCES:

A. *NASA Procedural Requirements for Limiting Orbital Debris Generation*, NPR 8715.6B, 6 February 2017
B. *Process for Limiting Orbital Debris*, NASA-STD-8719.14B, 25 April 2019
C. International Space Station Reference Trajectory, delivered December 2019
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. 5th ed. Northbrook, IL, Underwriters Laboratories, 2012
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. ODPO Guidance Email: Fasteners and Screws, John Opiela to Yusef Johnson, 12 February 2020

The intent of this report is to satisfy the orbital debris requirements listed in ref. (a) for the SPACE HAUC CubeSat launching on the SpX-22 Falcon 9 launch vehicle. 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.

This report serves as the 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 primary mission and are not presented here. This CubeSat will passively reenter, and therefore this ODAR will also serve as the End of Mission Plan (EOMP) for this CubeSat.

RECORD OF REVISIONS		
REV	**DESCRIPTION**	**DATE**
0	Original submission	August 2020

Section 1: Program Management and Mission Overview

SPACE HAUC is sponsored by the Human Exploration and Operations Mission Directorate at NASA Headquarters. The Program Executive is Sam Fonder. Responsible program/project manager and senior scientific and management personnel are as follows:

Supriya Chakrabarti, Principal Investigator, University of Massachusetts - Lowell

The following table summarizes the compliance status of SPACE HAUC, which will be flown on the SpX-22 mission to the International Space Station. SPACE HAUC 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 .914 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 releases

Program Milestone Schedule	
Task	**Date**
Delivery to Nanoracks	December 2020
Launch	March 12, 2021

Figure 1: Program Milestone Schedule

SPACE HAUC will be launched as a payload on the Space Falcon 9 launch vehicle executing the SpX-22 mission. The current launch date is projected to be March 12, 2021

Section 2: Spacecraft Description

Table 2 outlines its generic attributes.

Table 2: SPACE HAUC Attributes

CubeSat Names	CubeSat Quantity	CubeSat size (mm^3)	CubeSat Mass (kg)
SPACE HAUC	1	340 x 100 x 100	3.55

The following pages describe the SPACE HAUC CubeSat.

SPACE HAUC – University of Massachusetts - Lowell – 3U

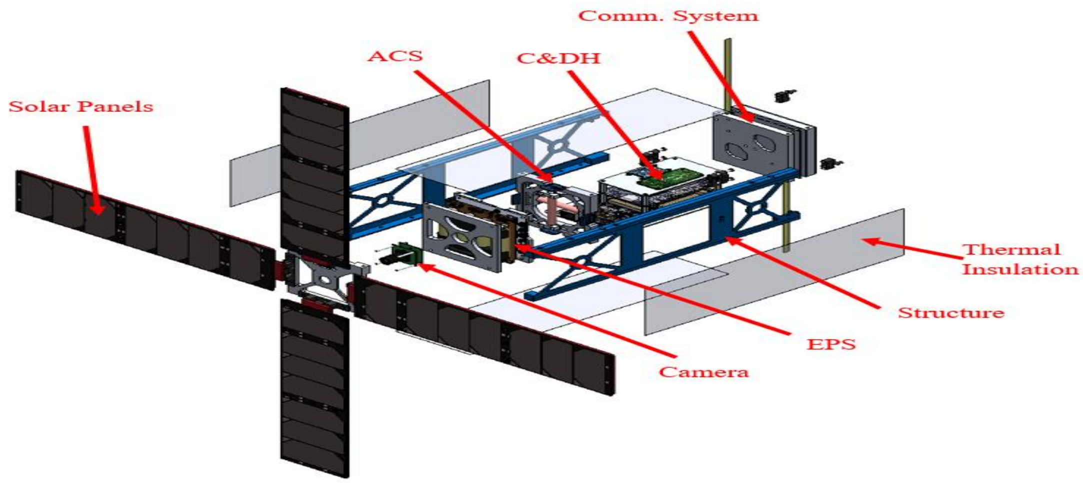

Figure 2: SPACE HAUC Exploded View

Overview

SPACE HAUC will demonstrate that high data transmission rates can be achieved by using a X-Band Phased-Array antenna with an electronically steered beam on a CubeSat.

CONOPS

Immediately upon deployment, SPACE HAUC will power up and determine if it is spin stabilized. If not, the Attitude Determination and Control System will stabilize the spin. It will then determine if it is sun pointed, if not the Attitude Determination and Control System will point SPACE HAUC at the sun. SPACE HAUC will then wait for a beacon signal from the ground. Upon receipt of the beacon, SPACE HAUC will take pictures of the sun and transmit them down. The process from waiting for the beacon signal will be repeated whenever the beacon signal is lost and will end upon re-entry.

Materials

The CubeSat structure is made of Aluminum 7075-T6. It contains all standard commercial off the shelf (COTS) materials, electrical components, PCBs and solar cells except for the RF front end board and patch antennas which are custom designed. The high-speed radio uses a ceramic patch antenna.

Hazards

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

Batteries

The electrical power storage system consists of 4 lithium-ion 18650 cells battery pack from GOMSpace with over-charge/current protection circuitry. The battery pack is ISS compliant.

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 SPACE HAUC CubeSat 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 SPACE HAUC.

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 prevent 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 lifetime of 0 .914 years maximum, SPACE HAUC 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.

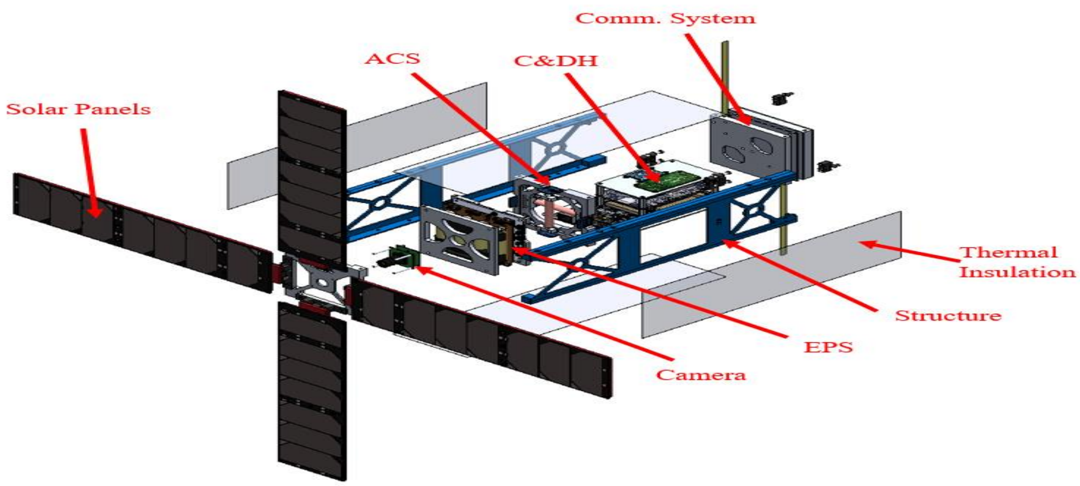

Figure 4: SPACE HAUC Exploded View

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

Equation 1: Mean Cross Sectional Area for Convex Objects

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

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 is 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

SPACE HAUC expected orbit at deployment has a 422 apogee and a 412 km perigee at a 51.6° inclination. With an area to mass ratio of ~0.0076 m^2/kg, DAS yields 0.914 years for orbit lifetime for its as-deployed state, which in turn is used to obtain the collision probability. SPACE HAUC is calculated to have a probability of collision of 0.0. Table 3 below provides complete results.

CubeSat		SPACE HAUC
	Mass (kg)	3.55
Stowed	Mean C/S Area (m^2)	0.0270
	Area-to Mass (m^2/kg)	0.0076
	Orbital Lifetime (yrs)	**0.914**
	Probability of collision (10^X)	**0.0000**
Deployed	Mean C/S Area (m^2)	0.0925
	Area-to Mass (m^2/kg)	0.0260
	Orbital Lifetime (yrs)	**0.361**
	Probability of collision (10^X)	**0.0000**

Solar Flux Table Dated 7/6/2020

Table 3: CubeSat Orbital Lifetime & Collision Probability

The probability of SPACE HAUC 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.

Assessment of spacecraft compliance with Requirements 4.5-1 shows SPACE HAUC to be compliant.

This ODAR also serves as the EOMP (End of Mission Plan)

Section 6: Assessment of Spacecraft Postmission Disposal Plans and Procedures

SPACE HAUC 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 will be achieved via passive atmospheric reentry even if the deorbit device does not deploy.

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

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

Equation 3: Area to Mass

$$\frac{0.027\ m^2}{3.55\ kg} = 0.0076\frac{m^2}{kg}$$

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

<u>DAS Orbital Lifetime Calculations:</u>
DAS inputs are: 422 km maximum apogee 412 km maximum perigee altitudes with an inclination of 51.6º at deployment no earlier than March 2021. An area to mass ratio of ~0.0076 m^2/kg for the SPACE HAUC CubeSat was used. DAS yields a 0.914 years orbit lifetime for SPACE HAUC 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 SPACE HAUC was performed. The assessment used DAS, 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.

3. Fasteners and similar materials that are composed of stainless steel or a lower melting point material will not be input into DAS, as suggested by guidance from the Orbital Debris Project Office (Reference I)

The majority of high melting point components demise upon reentry and SPACE HAUC complies with the 1:10,000 probability of Human Casualty Requirement 4.7-1. A breakdown of the determined probabilities follows:

Table 4: Requirement 4.7-1 Compliance by CubeSat

Name	Status	Risk of Human Casualty
SPACE HAUC	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 SPACE HAUC has a 1:0 probability, as none of its components have more than 15J of energy.

SPACE HAUC is compliant with Requirement 4.7-1 of NASA-STD-8719.14A.

Section 8: Assessment for Tether Missions

SPACE HAUC will not be deploying any tethers.

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/

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

cc: VA-H/Mr. Carney
VA-H1/Mr. Beaver
VA-H1/Mr. Haddox
VA-C/Mr. Higginbotham
AIS2/Mrs. Pariso
SA-D2/Mr. Frattin
SA-D2/Mr. Hale
SA-D2/Mr. Henry
Analex-3/Mr. Davis
Analex-22/Ms. Ramos

Appendix Index:

Appendix A. SPACE HAUC 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	**SPACE HAUC 3U CubeSat**	1	N/A	Box	N/A	**3546.4**	100.0	100.0	No	-	Demise
2	Spacecraft Bus Side -X	1	Aluminum 7075-T6	Box	133.00	133.0	100.0	340.0	No	-	Demise
3	Spacecraft Bus Side +X	1	Aluminum 7075-T6	Box	174.80	174.8	100.0	340.0	No	-	Demise
4	Solar Panel Frame	4	Aluminum 7075-T6	Panel	113.40	453.6	82.2	333.0	No	-	Demise
5	Camera Plate	1	Aluminum 7075-T6	Plate	76.20	76.2	96.0	96.0	No	-	Demise
6	Neutral Density Filter	2	UV Infused Silica	Cylinder	1.00	2.0	12.7	N/A	No	-	Demise
7	EPS Mount	1	Aluminum 7075-T6	Plate	69.80	69.8	96.0	96.0	No	-	Demise
8	Thermal Knife Base	2	PTFE	Box	2.40	4.8	5.0	25.0	No	-	Demise
9	Thermal Knife Traveler	2	PTFE	Box	1.71	3.4	5.0	25.0	No	-	Demise
10	Thermal Knife Heating Element	2	Nichrome	Box	0.10	0.2	0.3	25.0	No	-	Demise
11	Dyneema	2	Dyneema	Rope	2.00	4.0	2.0	200.0	No	-	Demise
12	Flight Computer Base	1	Aluminum 7075-T6	Plate	57.30	57.3	96.0	152.0	No	-	Demise
13	Auxiliary Board	1	Aluminum 7075-T6	Plate	16.60	16.6	95.0	110.0	No	-	Demise
14	Antenna Plate	1	PTFE	Plate	41.60	41.6	96.0	96.0	No	-	Demise
15	Deployment Switch Button	2	Aluminum 7075-T6	Cylinder	0.27	0.5	6.0	N/A	No	-	Demise
16	CESI CTJ30 Solar cells	28	InGaP, GaAs, Ge Substrate	Panel	2.60	72.8	40.0	80.0	No	-	Demise
17	Solar Panels Board	4	FR4 Tg170	Panel	112.00	448.0	82.6	326.0	No	-	Demise
18	Power Board (P31u EPS)	1	Commercial FR4	Board	100.00	100.0	89.3	92.9	No	-	Demise
19	Battery Board (BP4)	1	Commercial FR4	Board	66.00	66.0	94.0	84.0	No	-	Demise
20	Battery Cells	4	Lithium-ion	Cylinder	48.00	192.0	18.5	N/A	No	-	Demise
21	Deployment Switch	4	Thermoplastic, Bronze, Silver, Beryllium Copper, Stainless Steel	Box	2.50	10.0	6.4	16.3	No	-	Demise

22	Cabling	1	Copper and PTFE	Wire	250.00	250.0	N/A	N/A	No	-	Demise
23	Connector	1	Brass, Bronze, Beryllium Copper, Silver, Gold, PTFE, Polyamide, Polyester	Box	100.00	100.0	N/A	N/A	No	-	Demise
24	NanoSSOC-A60 Fine Sun Sensor	1	Aluminum 6082, Commercial FR4	Box	4.00	4.0	14.0	27.4	No	-	Demise
25	Fine Sun Sensor Board	1	Isola 370HR	Board	5.00	5.0	20.0	30.0	No	-	Demise
26	TSL2561 Coarse Sun Sensor	9	Commercial FR4	Board	1.00	9.0	16.5	19.1	No	-	Demise
27	Magnetorquer Boards	1	Isola 370HR	Board	50.00	50.0	95.0	95.0	No	-	Demise
28	Magnetorquer Rods	3	Copper Solenoid	Cylinder	30.00	90.0	8.5	70.0	No	-	Demise
29	ADRV9364	1	Rogers 4350, Isola 370HR	Board	60.00	60.0	62.0	100.0	No	-	Demise
30	ADRV-BoB	1	Isola 370HR	Board	80.00	80.0	76.2	152.4	No	-	Demise
31	Camera	1	Commercial FR4, Thermoplastic	Board with cylinder	24.00	24.0	30.0	N/A	No	-	Demise
32	Front-end Up/Down Converter Board	1	Rogers 4003C, Isola 370HR	Board	100.00	100.0	95.0	115.0	No	-	Demise
33	Front-end Beamformer Board	1	Rogers 4003C, Isola 370HR	Board	100.00	100.0	96.0	96.0	No	-	Demise
34	X-Band Patch Antenna Array	1	Rogers RT/Duroid 5880	Board	100.00	100.0	96.0	96.0	No	-	Demise
35	UHF Radio/Transceiver	1	Aluminum 6061-T651, Commercial FR4	Box	94.00	94.0	95.0	89.0	No	-	Demise
36	UHF Tape Antennas	2	1023 Carbon Steel, Mylar coating	Box	2.38	4.8	12.7	160.0	No	-	Demise
37	Multi-Layer Insulation	1	Dunmore - DM076, DM330	Panel	50.00	50.0	100.0	340.0	No	-	Demise
38	Kapton Tape	1	Dunmore - DM100, DM116	Tape	5.00	5.0	N/A	N/A	No	-	Demise
39	Heat Straps	5	Copper	Panel	25.00	125.0	40.0	40.0	No	-	Demise
40	Thermal Gap Pad	1	Bergquist TBP 800	-	5.00	5.0	N/A	N/A	No	-	Demise
41	Conformal Coating	1	NuSil CV-1152, Huntsman Arathane 5750-A/B	-	100.00	100.0	N/A	N/A	No	-	Demise
42	Thermal Epoxy	1	Eccobond 285/Catalyst 23LV - 25/2 BW	-	50.00	50.0	N/A	N/A	No	-	Demise

43	Structural Adhesive	1	3M Scotch-Weld 2216 B/A Gray - 5/7 BW	-	50.00	50.0	N/A	N/A	No	-	Demise
44	Encapsulate Epoxy	1	Skycast 2651; Catalyst 9 - 100/7 BW	-	10.00	10.0	N/A	N/A	No	-	Demise
45	M2.5x0.45x12 FH 90 Screws	4	18-8 Stainless Steel	Cylinder	0.55	2.2	2.5	N/A	Yes	2500°	Demise
46	M2.5x0.45x10 Sock Screws	8	18-8 Stainless Steel	Cylinder	0.66	5.3	2.5	N/A	Yes	2500°	Demise
47	M2.5x0.45x4 FH 90 Screws	8	18-8 Stainless Steel	Cylinder	0.23	1.8	2.5	N/A	Yes	2500°	Demise
48	M2.5 Split Washers	12	18-8 Stainless Steel	Cylinder	0.05	0.6	5.1	N/A	Yes	2500°	Demise
49	M2.5 Flat Washers	12	18-8 Stainless Steel	Cylinder	0.11	1.3	6.0	N/A	Yes	2500°	Demise
50	M2.5 Hex Nuts	14	18-8 Stainless Steel	Cylinder	0.26	3.6	5.0	N/A	Yes	2500°	Demise
51	M2.5x14 MF Standoff	2	18-8 Stainless Steel	Cylinder	1.92	3.8	4.5	N/A	Yes	2500°	Demise
52	M2.5 Unthreaded Spacers	2	18-8 Stainless Steel	Cylinder	0.24	0.5	4.5	N/A	Yes	2500°	Demise
53	M3x0.5x4.5 Helical Inserts	24	18-8 Stainless Steel	Cylinder	0.03	0.7	3.5	N/A	Yes	2500°	Demise
54	M3x0.5x6 FH 90 Screws	24	18-8 Stainless Steel	Cylinder	0.51	12.2	3.0	N/A	Yes	2500°	Demise
55	2-56x0.25 Vented Screws	4	18-8 Stainless Steel	Cylinder	0.27	1.1	2.2	N/A	Yes	2500°	Demise
56	2-56x0.5 FH 100 Screws	8	18-8 Stainless Steel	Cylinder	0.39	3.1	2.2	N/A	Yes	2500°	Demise
57	#2 Split Washers	8	18-8 Stainless Steel	Cylinder	0.04	0.3	4.4	N/A	Yes	2500°	Demise
58	#2 Flat Washers	8	18-8 Stainless Steel	Cylinder	0.19	1.5	6.4	N/A	Yes	2500°	Demise
59	2-56 Hex Nuts	12	18-8 Stainless Steel	Cylinder	0.19	2.3	4.8	N/A	Yes	2500°	Demise
60	2-56x1 MF Standoff	4	18-8 Stainless Steel	Cylinder	3.08	12.3	4.8	N/A	Yes	2500°	Demise
61	2-56x0.0625 Set Screws	1	18-8 Stainless Steel	Cylinder	0.01	0.0	2.2	N/A	Yes	2500°	Demise
62	4-40x2d Helical Inserts	12	Nitronic Stainless Steel	Cylinder	0.03	0.4	2.8	N/A	Yes	2500°	Demise
63	4-40x0.3125 Vented Screws	16	18-8 Stainless Steel	Cylinder	0.51	8.2	2.8	N/A	Yes	2500°	Demise
64	4-40x1.625 Sock Screws	4	18-8 Stainless Steel	Cylinder	2.10	8.4	2.8	N/A	Yes	2500°	Demise
65	4-40x0.5625 Sock Screws	4	18-8 Stainless Steel	Cylinder	0.83	3.3	2.8	N/A	Yes	2500°	Demise
66	4-40x0.75 Sock Screws	4	18-8 Stainless Steel	Cylinder	1.24	5.0	2.8	N/A	Yes	2500°	Demise
67	4-40x0.375 FH 82 Screws	6	18-8 Stainless Steel	Cylinder	0.67	4.0	2.8	N/A	Yes	2500°	Demise

68	4-40x1 Sock Screws	4	18-8 Stainless Steel	Cylinder	2.44	9.8	2.8	N/A	Yes	2500°	Demise
69	#4 Split Washers	26	18-8 Stainless Steel	Cylinder	0.07	1.8	5.3	N/A	Yes	2500°	Demise
70	#4 Flat Washers	26	18-8 Stainless Steel	Cylinder	0.14	3.6	6.4	N/A	Yes	2500°	Demise
71	4-40 Hex Nuts	26	18-8 Stainless Steel	Cylinder	0.54	14.0	6.4	N/A	Yes	2500°	Demise
72	#4 Unthreaded Spacers	4	18-8 Stainless Steel	Cylinder	1.48	5.9	5.0	N/A	Yes	2500°	Demise
73	#4 Unthreaded Spacers	4	18-8 Stainless Steel	Cylinder	0.42	1.7	4.8	N/A	Yes	2500°	Demise
74	4-40x0.5 MF Standoffs	4	18-8 Stainless Steel	Cylinder	1.91	7.6	4.8	N/A	Yes	2500°	Demise
75	4-40x0.3125 FF Standoffs	8	18-8 Stainless Steel	Cylinder	0.94	7.5	4.8	N/A	Yes	2500°	Demise
76	#4 Unthreaded Spacers	4	18-8 Stainless Steel	Cylinder	0.49	2.0	4.8	N/A	Yes	2500°	Demise
77	4-40x0.3125 MF Standoffs	4	18-8 Stainless Steel	Cylinder	1.12	4.5	4.8	N/A	Yes	2500°	Demise
78	4-40x0.25 MF Standoffs	4	18-8 Stainless Steel	Cylinder	1.06	4.2	4.8	N/A	Yes	2500°	Demise
79	180º Torsion Springs	8	302 Stainless Steel	Cylinder	0.37	3.0	6.3	N/A	Yes	2500°	Demise
80	Compression Springs	4	Cadmium Plated Music-Wire Steel	Cylinder	0.29	1.2	4.6	N/A	Yes	2500°	Demise
81	Hinge Pin	4	Aluminum 7075	Pin	1.02	4.1	3.0	53.0	No	-	Demise
82	M14.5x0.5 Retaining Rings	2	Aluminum 7075	Cylinder	0.53	1.1	14.5	N/A	No	-	Demise