Orbital Debris Assessment Report

BSS1

per NASA-STD 8719.14A

Signature Page

Benchmark Space Systems, Inc

4/8/2020

Matthew Shea
Chief Operations Officer

NearSpace Launch, Inc.

4/8/2020

Matt Orvis
Project Engineer

Sterk Solutions Corporation

4/1/2020

Mike H. Miller
Licensing Engineer

REFERENCES:

A. *NASA Procedural Requirements for Limiting Orbital Debris Generation,* NPR 8715.6A, *5* February 2008
B. *Process for Limiting Orbital Debris,* NAS A-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.* 1JL 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 Emai1:6U CubcSat Battery Non Passivation Suzanne Aleman to Justin Treptow, 8 August 2017

This report is intended to satisfy the orbital debris requirements listed in *NASA Procedural Requirements for Limiting Orbital Debris Generation,* NPR 8715.6A, *5* February 2008, for the ThinSat-1 mission.

Sections 1 through 8 of *Process for Limiting Orbital Debris*, NAS A-STD-8719.14A, 25 May 2012, are addressed in this document; sections 9 through 14 are in the domain of the launch provider and are addressed by others.

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

The following table summarizes the compliance status of the BSS-1 spacecraft. It is fully compliant with all applicable requirements.

Requirements	**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	Batteries incapable of debris producing failure
4.4-2	Compliant	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	

Table 1 Compliance Assessment per Requirement

Section 1: Mission Overview

The overall goal of the BSS1 mission, is to demonstrate the performance of Benchmark Space System's DFAST propulsion system. Performance measurements include; on-orbit pressurization time and power required, pressure tank temperature profiles and thruster induced velocity changes.

Section 2: Spacecraft Description

The spacecraft is a single unit with the dimensions of 100mm x 100mm x 340.5mm. The total dry mass is about 5 kg. See Figure 1.

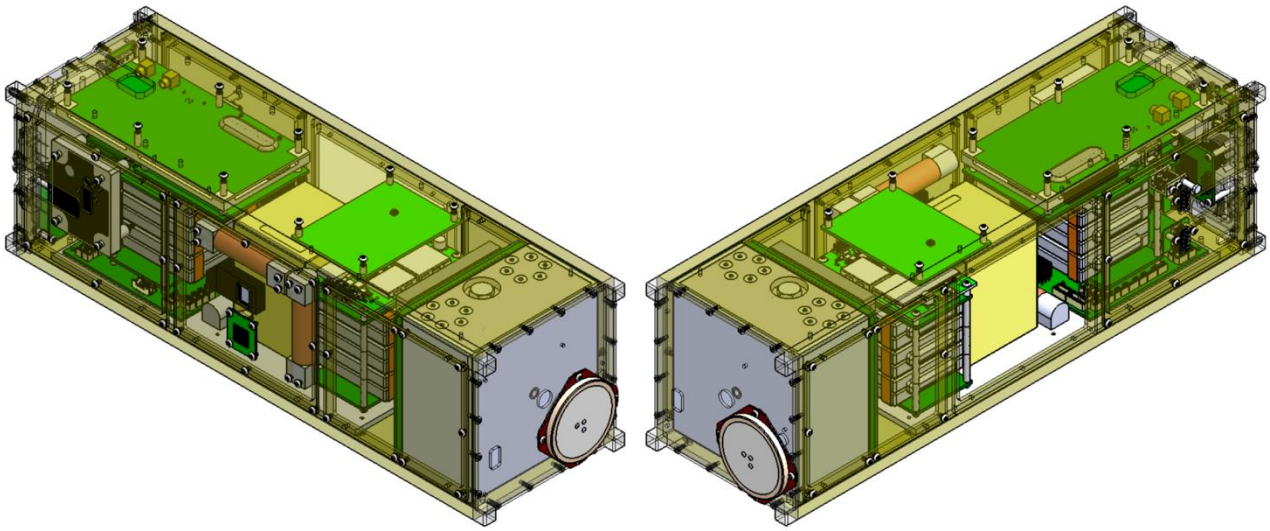

Figure 1 BSS-1 3U Cubesat

.

Hazards

Benchmark Space System's DFAST propulsion system, approximately 0.5U in volume is mounted close to one end of the spacecraft. The propellant is an inert, non-toxic powder (about 30 grams mass) stored unpressurized for launch. In orbit, the system heats up propellant containers to above 200C to initiate a reaction that converts the powder into gas made up primarily of nitrogen, carbon dioxide, and carbon monoxide. The gas is stored, then upon command, regulated to working pressure, flowed thru a valve and ejected from the spacecraft via a rocket nozzle to generate thrust.

Batteries

- Batteries: Dual Lipo Battery Pack UL 925050 Tenergy x 8 (Bus Power); Lipo Battery UL 925050 x 1 (Black Box)

The EPS is a direct energy transfer system using a solar array producing approximately 3.47W of orbit average power to charge the 8.8 A-hr battery system. The total energy storage capacity is 65 W-hrs. The solar arrays utilize standard Alta Devices flexible photovoltaic cells; the batteries are COTS Tenergy 925050 Li-Polymer cells. The Advanced EPS board controls the charging through four MPPT modules and load switching of the system.

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.

Only the inert gaseous propellant will be released. No release of any object is planned, 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.

The probability of battery explosion is very low, and, due to the very small mass of the satellite the effect of an explosion on the far-term LEO environment is negligible, per HQ OSMA Policy Memo/Email to 8719.14: CubeSat Battery Non-Passivation, Suzanne Aleman to Justin Treptow, 10, March 2014

The batteries meet Reg. 56450 (4.4-2), per this reference, by virtue of the HQ OSMA policy regarding battery disconnect stating "Cube Sats as a satellite class need not disconnect their batteries if flown in LEO with orbital lifetimes less than 25 years."

Assessment of spacecraft compliance with Requirements 4.4-1 through 4.4-4 shows that the 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 (MCSA) and orbital lifetime.

See Appendix for DAS Analysis Input Data and Output Results. This shows that the probability of an on orbit collision with debris or meteoroids greater than 10 cm in diameter is "less than 0.00000". This satisfies the 0.001 maximum probability requirement 4.5-l.

The spacecraft 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 it to be compliant.

Requirement 4.5-2 is not applicable to this mission.

Section 6: Assessment of Spacecraft Postmission Disposal Plans and Procedures

The spacecraft all will naturally decay from orbit within 25 years after end of the mission, satisfying requirement 4.6- l.

Planning for spacecraft maneuvers to accomplish post-mission disposal is not applicable. Disposal is achieved via passive atmospheric reentry.

Summary of DAS 3.0 Orbital Lifetime Calculations:

DAS inputs are: 300 km circular orbit, with an inclination of 137° at deployment no earlier than August 2020.

The following equation is utilized to determine the mean CSA, or MCSA.

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

Mean Cross Sectional Area for Convex Objects

The spacecraft is a single unit with the dimensions of 0.1 m x 0.1 m x 0.34 m.

w = 0.1 m
h = 0.34 m
l = 0.1 m

MCSA = [2 * (0.1 *0.1) + 4 * (0.1 * 0.34)]/4
MCSA = 0.039 m^2

Area to Mass Ratio = 0.039 m^2 / 5 kg = 0.0078 m^2 / kg

Based on a dry mass of 5 kg and an effective cross sectional area of 0.039 square meters, the area to mass ratio is 0.0078 m^2 / kg, and per DAS, the orbit lifetime of the spacecraft, considering only passive decay and neglecting propulsion effects, is estimated to be 94 days. See Figure 1 below.

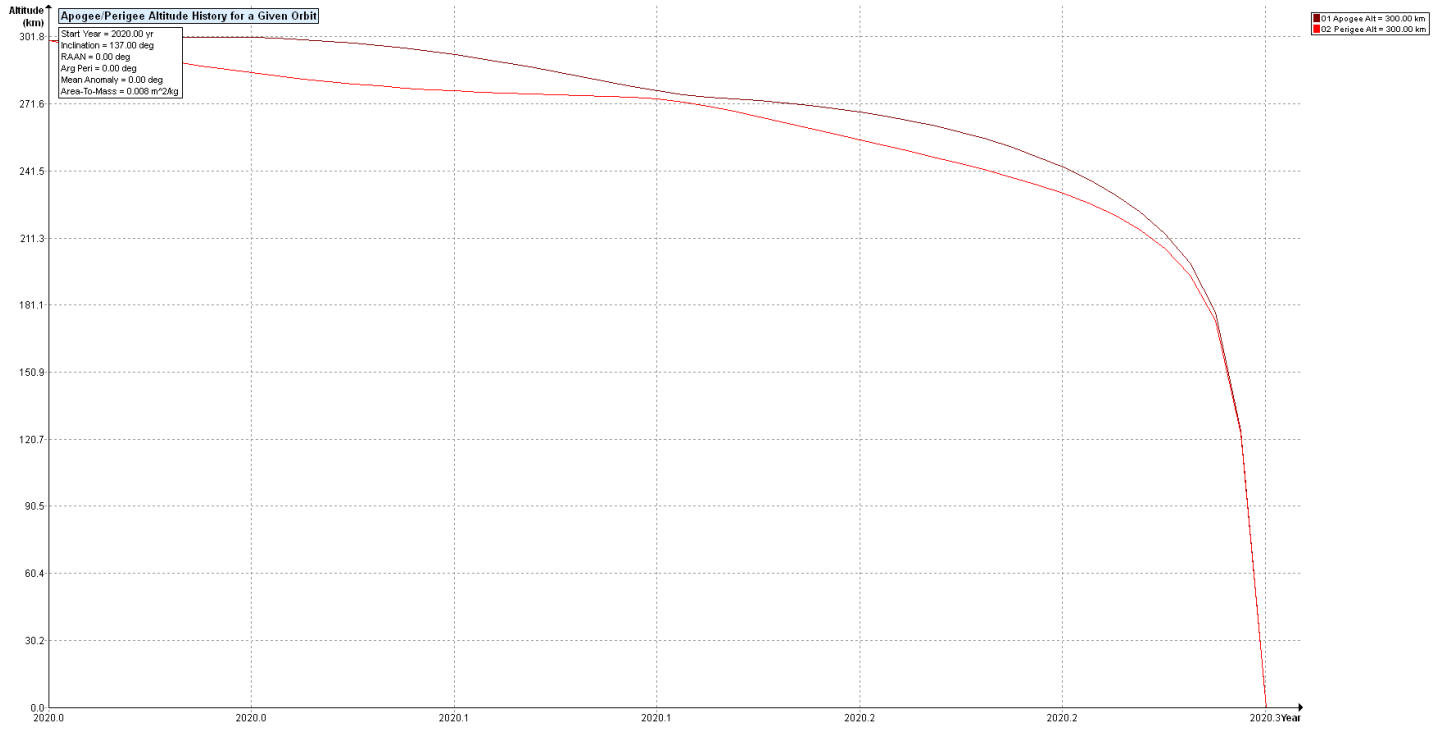

Figure 1 Altitude vs. Time For BSS1 Spacecraft, for Passive Orbit Decay

From the document "BSS1 Propulsion Experiment CONOPS, And Thrust Effects on the Satellite Orbit", the total theoretical delta V that could be imparted to the spacecraft from the propulsion experiment is at most 4.2 meters per second. The maximum effect this could have is to extend orbit lifetime by 30 days, for a total of

94 + 30 = 124 days in orbit, maximum.

The assessment of the spacecraft illustrates it is compliant with Requirements 4.6-1 through 4.6-5.

Section 7: Assessment of Spacecraft Reentry Hazards

A detailed assessment of the components of the spacecraft was performed using DAS 2.1.1, to verify Requirement 4.7-1. See Appendix for a complete log of DAS inputs and outputs. The analysis provides a bounding analysis for characterizing the survivability of a component during re-entry. It is conservative in that when it shows terminal energy of a component surviving reentry, it is does not consider any loss material from ablation or charring. Both of these may for some materials decrease the mass and dimensions of the re-entering components, reducing the risk below that calculated.

Two components are not predicted to demise upon reentry; these are described in the following Table. The risk of human casualty calculated by DAS is 1:40500.

Component	Material	Mass, kg	Dimensions, m	Casualty Area, m^2	Energy, J
Chemical Storage Tank	Titanium	0.085	.027 dia x .086 l	.84	32
Expansion Tank / Manifold	Titanium	0.253	.066 x .083 x .047	.45	127

Table 2 Non Demising Components

The spacecraft complies with the less than 1:10,000 probability of Human Casualty Requirement 4.7-1.

The satellite thus is in compliance with Requirement 4.7-1 of NASA-STD-8719.14A.

Section 8: Assessment for Tether Missions

No tethers are used. Requirement 4.8-1 is satisfied.

Section 9 through 14:

ODAR sections 9 through 14 pertain to the launch vehicle, and are not covered here.

Appendix

```
03 30 2020; 19:28:14PM Activity Log Started
03 30 2020; 19:28:14PM Opened Project C:\Users\Mike\Documents\All
SatLicensing\BENCHMARK\ODAR\DAS\BSS DAS March 30\
03 30 2020; 19:28:27PM Mission Editor Changes Applied
03 30 2020; 19:28:38PM Processing Requirement 4.3-1:     Return Status :  Not Run

=====================
No Project Data Available
=====================

=============== End of Requirement 4.3-1 ===============
03 30 2020; 19:30:32PM Processing Requirement 4.5-1:     Return Status :  Passed

==============
Run Data
==============

**INPUT**

      Space Structure Name = BSS-1
      Space Structure Type = Payload
      Perigee Altitude = 300.000000 (km)
      Apogee Altitude = 300.000000 (km)
      Inclination = 137.000000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass Ratio = 0.007800 (m^2/kg)
      Start Year = 2020.000000 (yr)
      Initial Mass = 5.000000 (kg)
      Final Mass = 5.000000 (kg)
      Duration = 2.000000 (yr)
      Station-Kept = False
      Abandoned = True
      PMD Perigee Altitude = -1.000000 (km)
      PMD Apogee Altitude = -1.000000 (km)
      PMD Inclination = 0.000000 (deg)
      PMD RAAN = 0.000000 (deg)
      PMD Argument of Perigee = 0.000000 (deg)
      PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

      Collision Probability = 0.000000
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range
      Status = Pass

==============

=============== End of Requirement 4.5-1 ===============
03 30 2020; 19:30:52PM Requirement 4.5-2:  Compliant
03 30 2020; 19:31:05PM Processing Requirement 4.6   Return Status :  Passed

==============
Project Data
==============
```

```
**INPUT**

      Space Structure Name = BSS-1
      Space Structure Type = Payload

      Perigee Altitude = 300.000000 (km)
      Apogee Altitude = 300.000000 (km)
      Inclination = 137.000000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Area-To-Mass Ratio = 0.007800 (m^2/kg)
      Start Year = 2020.000000 (yr)
      Initial Mass = 5.000000 (kg)
      Final Mass = 5.000000 (kg)
      Duration = 2.000000 (yr)
      Station Kept = False
      Abandoned = True
      PMD Perigee Altitude = -1.000000 (km)
      PMD Apogee Altitude = -1.000000 (km)
      PMD Inclination = 0.000000 (deg)
      PMD RAAN = 0.000000 (deg)
      PMD Argument of Perigee = 0.000000 (deg)
      PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

      Suggested Perigee Altitude = 300.000000 (km)
      Suggested Apogee Altitude = 300.000000 (km)
      Returned Error Message = Reentry during mission (no PMD req.).

      Released Year = 2020 (yr)
      Requirement = 61
      Compliance Status = Pass

==============

=============== End of Requirement 4.6 ===============
03 30 2020; 19:31:06PM *********Processing Requirement 4.7-1
      Return Status :  Passed

***********INPUT****
 Item Number = 1

name = BSS-1
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 5.000000
Thermal Mass = 5.000000
Diameter/Width = 0.100000
Length = 0.300000
Height = 0.100000

name = NSL 3U CubeSat Chassis
quantity = 1
parent = 1
materialID = 8
```

```
type = Box
Aero Mass = 1.210000
Thermal Mass = 1.210000
Diameter/Width = 0.100000
Length = 0.290000
Height = 0.100000

name = NSL 3x1 Deploy Solar Array
quantity = 4
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.104000
Thermal Mass = 0.104000
Diameter/Width = 0.083000
Length = 0.995000

name = NSL Duplex Antenna
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.069000
Thermal Mass = 0.069000
Diameter/Width = 0.050000
Length = 0.050000
Height = 0.020000

name = NSL Simplex Antenna
quantity = 2
parent = 1
materialID = 23
type = Box
Aero Mass = 0.015000
Thermal Mass = 0.015000
Diameter/Width = 0.035000
Length = 0.035000
Height = 0.010000

name = NSL RBF Switch Assembly
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.005000
Thermal Mass = 0.005000
Diameter/Width = 0.015000
Length = 0.015000
Height = 0.015000

name = Rail Switches
quantity = 4
parent = 1
materialID = 27
type = Box
Aero Mass = 0.002000
Thermal Mass = 0.002000
Diameter/Width = 0.010000
Length = 0.020000
Height = 0.007000
```

```
name = NSL BlackBOX Patch Antenna
quantity = 2
parent = 1
materialID = 40
type = Box
Aero Mass = 0.007000
Thermal Mass = 0.007000
Diameter/Width = 0.025000
Length = 0.025000
Height = 0.015000

name = NSL BlackBOX Patch PCB
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.031000
Thermal Mass = 0.031000
Diameter/Width = 0.080000
Length = 0.100000
Height = 0.005000

name = NSL Lipo Battery UL 925050 Single
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.020000
Thermal Mass = 0.020000
Diameter/Width = 0.050000
Length = 0.055000
Height = 0.007000

name = NSL BlackBOX Patch Frame
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.008000
Thermal Mass = 0.008000
Diameter/Width = 0.082000
Length = 0.100000
Height = 0.005000

name = NSL EPS / COMM
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.130000
Thermal Mass = 0.130000
Diameter/Width = 0.087000
Length = 0.090000
Height = 0.014000

name = NSL Dual Lipo Battery Pack UL 925050 Tenergy
quantity = 6
parent = 1
materialID = 8
```

```
type = Box
Aero Mass = 0.083000
Thermal Mass = 0.083000
Diameter/Width = 0.050000
Length = 0.055000
Height = 0.017000

name = Cabling
quantity = 1
parent = 1
materialID = 54
type = Cylinder
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.005000
Length = 1.000000

name = Fasteners
quantity = 1
parent = 1
materialID = 52
type = Cylinder
Aero Mass = 0.065000
Thermal Mass = 0.065000
Diameter/Width = 0.005000
Length = 1.000000

name = NSL D2F Duplex Module
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.136000
Thermal Mass = 0.136000
Diameter/Width = 0.060000
Length = 0.118000
Height = 0.060000

name = NSL S2F Backup Simplex
quantity = 2
parent = 1
materialID = 23
type = Box
Aero Mass = 0.056000
Thermal Mass = 0.056000
Diameter/Width = 0.045000
Length = 0.082000
Height = 0.010000

name = NSL ADACS Coil
quantity = 3
parent = 1
materialID = 19
type = Cylinder
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.008000
Length = 0.068000

name = NSL ADACS Module
```

```
quantity = 1
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.010000
Thermal Mass = 0.010000
Diameter/Width = 0.042000
Length = 0.070000

name = NSL Peak Power Tracker
quantity = 2
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.009000
Thermal Mass = 0.009000
Diameter/Width = 0.040000
Length = 0.050000

name = NSL Energetic Partical Detector - Old
quantity = 3
parent = 1
materialID = 23
type = Box
Aero Mass = 0.005000
Thermal Mass = 0.005000
Diameter/Width = 0.016000
Length = 0.028000
Height = 0.007000

name = NSL Energetic Particle Detector - New
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.003000
Thermal Mass = 0.003000
Diameter/Width = 0.015000
Length = 0.032000
Height = 0.010000

name = CST
quantity = 2
parent = 1
materialID = 66
type = Cylinder
Aero Mass = 0.085000
Thermal Mass = 0.085000
Diameter/Width = 0.027000
Length = 0.086000

name = ET/Manifold
quantity = 1
parent = 1
materialID = 66
type = Box
Aero Mass = 0.253000
Thermal Mass = 0.253000
Diameter/Width = 0.066000
Length = 0.083000
```

```
Height = 0.047000

name = PCB
quantity = 1
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.020000
Thermal Mass = 0.020000
Diameter/Width = 0.090000
Length = 0.090000

name = Regulator
quantity = 1
parent = 1
materialID = 14
type = Cylinder
Aero Mass = 0.076000
Thermal Mass = 0.076000
Diameter/Width = 0.026000
Length = 0.028000

name = Valve
quantity = 1
parent = 1
materialID = 59
type = Cylinder
Aero Mass = 0.007000
Thermal Mass = 0.007000
Diameter/Width = 0.010000
Length = 0.028000

name = Nozzle
quantity = 1
parent = 1
materialID = 5
type = Cylinder
Aero Mass = 0.005000
Thermal Mass = 0.005000
Diameter/Width = 0.012700
Length = 0.019000

name = Enclosure
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.118000
Thermal Mass = 0.118000
Diameter/Width = 0.092000
Length = 0.092000
Height = 0.048000

name = Fittings
quantity = 7
parent = 1
materialID = 59
type = Cylinder
Aero Mass = 0.008000
Thermal Mass = 0.008000
```

```
Diameter/Width = 0.008000
Length = 0.025000

name = Extra Battery PCB
quantity = 2
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.015000
Thermal Mass = 0.015000
Diameter/Width = 0.040000
Length = 0.070000

name = MAI-25
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.250000
Thermal Mass = 0.250000
Diameter/Width = 0.050000
Length = 0.065000
Height = 0.050000

name = NovAtel OEM 719
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.031000
Thermal Mass = 0.031000
Diameter/Width = 0.046000
Length = 0.071000
Height = 0.011000

name = NovAtel GPS Antenna
quantity = 1
parent = 1
materialID = 19
type = Cylinder
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.020000
Length = 0.060000

name = NSL GPS
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.010000
Thermal Mass = 0.010000
Diameter/Width = 0.025000
Length = 0.045000
Height = 0.010000

name = NSL Optical Bench
quantity = 1
parent = 1
materialID = 8
```

```
type = Flat Plate
Aero Mass = 0.166000
Thermal Mass = 0.166000
Diameter/Width = 0.090000
Length = 0.215000

name = NSL Grid IR Sensor
quantity = 3
parent = 1
materialID = 23
type = Box
Aero Mass = 0.006000
Thermal Mass = 0.006000
Diameter/Width = 0.025000
Length = 0.044000
Height = 0.006000

name = NSL Plasma Probe
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.012000
Thermal Mass = 0.012000
Diameter/Width = 0.025000
Length = 0.040000
Height = 0.009000

name = Ballast Mass
quantity = 1
parent = 1
materialID = 19
type = Box
Aero Mass = 0.680000
Thermal Mass = 0.680000
Diameter/Width = 0.050000
Length = 0.051000
Height = 0.035000

**************OUTPUT****
Item Number = 1

name = BSS-1
Demise Altitude = 77.998505
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL 3U CubeSat Chassis
Demise Altitude = 74.484131
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL 3x1 Deploy Solar Array
Demise Altitude = 77.813812
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
```

```
name = NSL Duplex Antenna
Demise Altitude = 76.425797
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL Simplex Antenna
Demise Altitude = 77.297508
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL RBF Switch Assembly
Demise Altitude = 77.085228
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Rail Switches
Demise Altitude = 77.883011
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL BlackBOX Patch Antenna
Demise Altitude = 77.263054
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL BlackBOX Patch PCB
Demise Altitude = 77.616592
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL Lipo Battery UL 925050 Single
Demise Altitude = 77.201408
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL BlackBOX Patch Frame
Demise Altitude = 77.867119
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL EPS / COMM
Demise Altitude = 76.510757
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL Dual Lipo Battery Pack UL 925050 Tenergy
Demise Altitude = 75.369476
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
```

```
name = Cabling
Demise Altitude = 76.647202
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Fasteners
Demise Altitude = 77.808167
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL D2F Duplex Module
Demise Altitude = 77.154892
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL S2F Backup Simplex
Demise Altitude = 76.966736
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL ADACS Coil
Demise Altitude = 76.153893
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL ADACS Module
Demise Altitude = 77.716728
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL Peak Power Tracker
Demise Altitude = 77.628441
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL Energetic Partical Detector - Old
Demise Altitude = 77.523972
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL Energetic Particle Detector - New
Demise Altitude = 77.769447
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = CST
Demise Altitude = 0.000000
Debris Casualty Area = 0.840293
Impact Kinetic Energy = 32.489567

************************************
```

```
name = ET/Manifold
Demise Altitude = 0.000000
Debris Casualty Area = 0.446865
Impact Kinetic Energy = 126.843567

************************************
name = PCB
Demise Altitude = 77.724625
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Regulator
Demise Altitude = 74.838005
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Valve
Demise Altitude = 76.499916
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Nozzle
Demise Altitude = 77.012993
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Enclosure
Demise Altitude = 76.658714
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Fittings
Demise Altitude = 75.872894
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Extra Battery PCB
Demise Altitude = 77.553406
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = MAI-25
Demise Altitude = 73.906212
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NovAtel OEM 719
Demise Altitude = 77.366920
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
```

```
name = NovAtel GPS Antenna
Demise Altitude = 74.511421
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL GPS
Demise Altitude = 77.558716
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL Optical Bench
Demise Altitude = 76.495461
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL Grid IR Sensor
Demise Altitude = 77.688980
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = NSL Plasma Probe
Demise Altitude = 77.400192
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Ballast Mass
Demise Altitude = 68.340126
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************

=============== End of Requirement 4.7-1 ===============
03 30 2020; 19:35:27PM Science and Engineering - Apogee/Perigee History for a Given
Orbit

**INPUT**

      Perigee Altitude = 300.000000 (km)
      Apogee Altitude = 300.000000 (km)
      Inclination = 137.000000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Area-To-Mass Ratio = 0.007800 (m^2/kg)
      Start Year = 2020.000000 (yr)
      Integration Time = 2.000000 (yr)

**OUTPUT**

      Plot
03 30 2020; 19:35:37PM Science and Engineering - Orbit Lifetime/Dwell Time

**INPUT**
```

```
      Start Year = 2020.000000 (yr)
      Perigee Altitude = 300.000000 (km)
      Apogee Altitude = 300.000000 (km)
      Inclination = 137.000000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Area-To-Mass Ratio = 0.007800 (m^2/kg)

**OUTPUT**

      Orbital Lifetime from Startyr = 0.257358 (yr)
      Time Spent in LEO during Lifetime  = 0.257358 (yr)
      Last year of Propagation = 2020 (yr)
      Returned Error Message: Object reentered
03 30 2020; 19:36:02PM Project Data Saved To File
```