Orbital Debris Assessment Report

GEARRS-3

per NASA-STD 8719.14A

Signature Page

4/9/2021

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4/8/2021

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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 GEARRS-3 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	July 2019
1	Update for 2021 Launch	April 2021

The following table summarizes the compliance status of the spacecraft. They all are 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	
4.5-2	TBD Damage from small objects	
4.6-1 through 4.6-4	Compliant	Lifetime 15 years
4.7-1	Compliant	Non-credible risk of human casualty
4.8-1	Not Applicable	No Tethers

Table 1 Compliance Assessment per Requirement

Section 1: Mission Overview

The overall goal of the GEARRS-3 mission, is to correlate Solar Activity to the Electron Density in the Near-Earth (LEO) Plasma Field. The spacecraft will carry an Energetic Particle Detector and a Langmuir Probe. The satellite will be launched as a payload aboard a Virgin Orbit Launcher1 rocket, scheduled to launch from Anderson Air Force Base, Guam, No Earlier Than June 1, 2021. The satellite will be inserted into a circular orbit at 500 km at an inclination of 45 degrees from the equator.

Section 2: Spacecraft Description

The spacecraft is a 3U cubesat unit with the dimensions of 10 cm X 10 cm X 30 cm The total mass is about 3.171 Kg. See Figure 1.

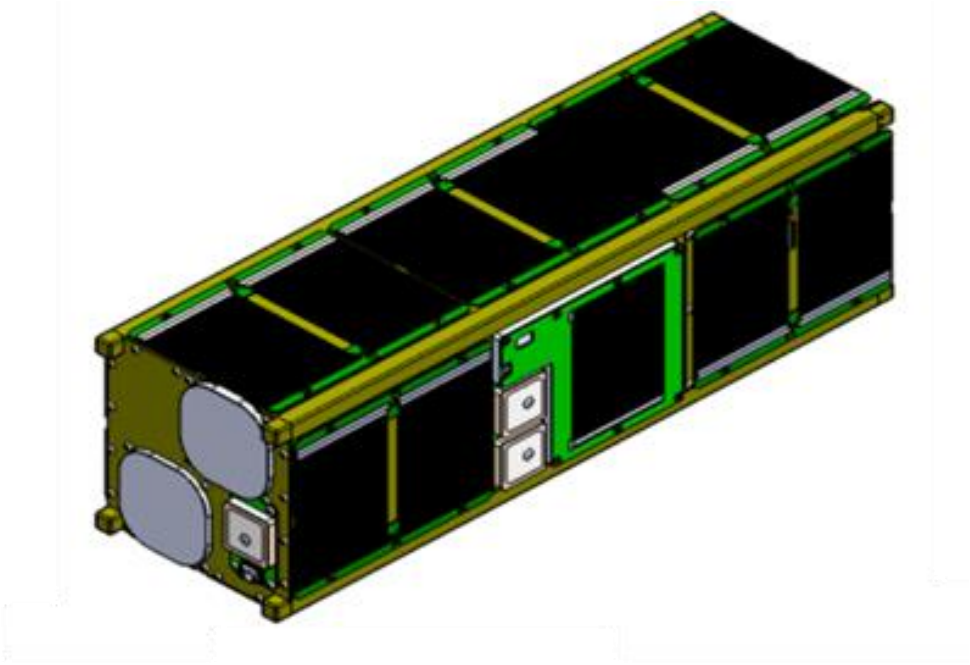

Figure 1 GEARRS-3 3U Cubesat

Hazards

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

Batteries

The spacecraft carries a total of 17 COTS Tenergy cells, UL 925050.

The Tenergy Model 925050 pouch type cell, uses Polymer Lithium ion chemistry. It stores 2200 mAh at 3.7 volts. The UL listing number of the battery is SR925959 (30256-0). It is used with a battery circuit protection module providing over-charge/over-current protection and over-discharge protection circuitry.

Tests have been conducted to demonstrate compliance with JSC EP-WI-032 “Statement of Work: Engineering Evaluation, Qualification and Flight Acceptance Tests for Lithium-ion Cells and Battery Packs for Small Satellite Systems.”

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, 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, and the short orbital lifetime, the effect of an explosion on the far term LEO environment is negligible.

In addition due to the very small mass of the battery, and the foil pouch construction not supporting pressure buildup prior to breach, the effect of battery overpressure would not cause any release of debris from the satellite.

The batteries meet Reg. 56450 (4.4-2), per this reference, by virtue of the HQ OSMA policy regarding battery disconnect stating "Cubesats 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 the satellite is compliant.

Section 5: Assessment of Spacecraft Potential for On Orbit Collisions

4.5-1 Probability of Collision with Large Debris

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.

From DAS, the orbit lifetime will be approximately 15 years and probability of collision with space objects larger than 10 cm in diameter during the orbital lifetime of the spacecraft, is 1.4534E-07. 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.

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

4.5-2 Probability of Damage from Small Objects

Assessment of spacecraft compliance with Requirements 4.5-2 shows it to be compliant.

Section 6: Assessment of Spacecraft Postmission Disposal Plans and Procedures

4.6.1 Remove from LEO to Reduce Collision Threat

The spacecraft will naturally decay from orbit within 25 years after end of the mission, satisfying requirement 4.6- l. No systems are required. Requirements 4.6-2, 4.6-3 and 4.6-4 therefore are not applicable.

Summary of DAS 3.1.2 Orbital Lifetime Calculations:

DAS inputs are: 500 km circular orbit, with an inclination of 45° at deployment no earlier than June 2021. The total mass of the spacecraft is 3.171 kg, and per DAS, the equivalent cross sectional area (minimum of all cases, for maximum lifetime) is 0.009 m^2. From DAS, the lifetime for this maximum case will be 15 years.

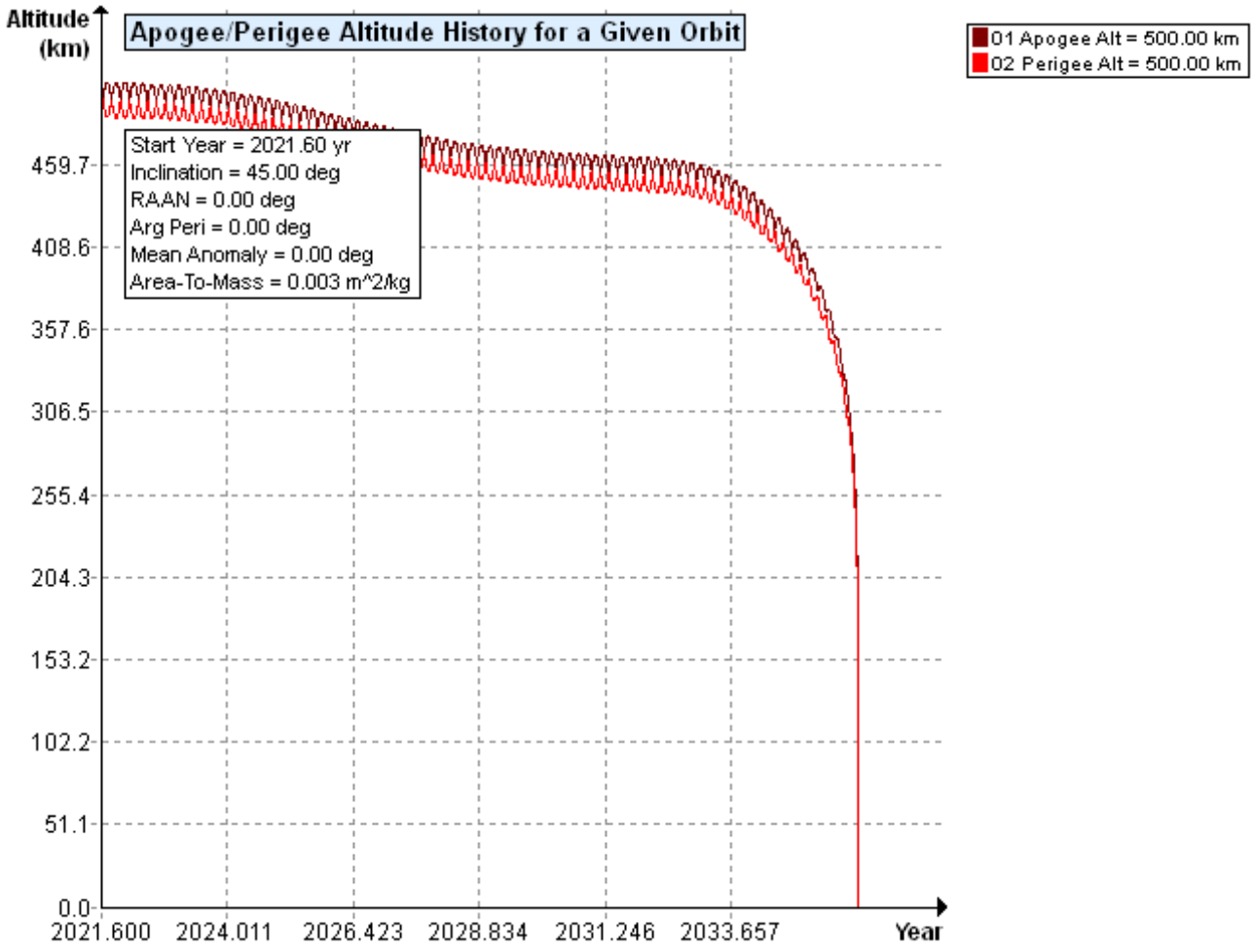

Figure 2 Altitude vs. Time GEARRS-3 Spacecraft

The assessment of the spacecraft illustrates it is compliant with Requirements 4.6-1 through 4.6-4

Section 7: Assessment of Spacecraft Reentry Hazards

4.7-1 Limit Number and Size of Debris Fragments Surviving Reentry

A detailed assessment of the components of the spacecraft was performed using DAS 3.1.2, 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.

The surviving components are shown in Table 2.

Surviving Component	Original Mass, kg	Terminal Energy, Joules	Casualty Area	Total Spacecraft Risk of Human Casualty
Rail Switches	**0.002**	**0.28**	**1.5**	**N/A**
				1:100000000

Table 2: Surviving Component Analysis

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 the spacecraft has a calculated Risk of Human Casualty from DAS, of 1:100000000. The maximum terminal energy among all the surviving components is 3.21 Joules.

The rest of the components demise upon reentry the spacecraft comply 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

4.8-1 Collision Hazards of Space Tethers
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

```
04 01 2021; 12:14:26PM Activity Log Started
04 01 2021; 12:14:26PM Opened Project C:\Users\mille\Downloads\GEARRS\GEARRS\
04 01 2021; 12:15:17PM Mission Editor Changes Applied
04 01 2021; 12:15:17PM Project Data Saved To File
04 01 2021; 12:17:55PM Mission Editor Changes Applied
04 01 2021; 12:17:55PM Project Data Saved To File
04 01 2021; 12:22:51PM Mission Editor Changes Applied
04 01 2021; 12:22:51PM Project Data Saved To File
04 01 2021; 12:36:56PM Processing Requirement 4.5-1:     Return Status :  Passed
==============
Run Data
==============
**INPUT**
      Space Structure Name = GEARRS-3
      Space Structure Type = Payload
      Perigee Altitude = 500.000 (km)
      Apogee Altitude = 500.000 (km)
      Inclination = 45.000 (deg)
      RAAN = 0.000 (deg)
      Argument of Perigee = 0.000 (deg)
      Mean Anomaly = 0.000 (deg)
      Final Area-To-Mass Ratio = 0.0028 (m^2/kg)
      Start Year = 2021.000 (yr)
      Initial Mass = 3.171 (kg)
      Final Mass = 3.171 (kg)
      Duration = 2.000 (yr)
      Station-Kept = False
      Abandoned = True
**OUTPUT**
      Collision Probability = 1.4534E-07
      Returned Message: Normal Processing
      Date Range Message: Normal Date Range
      Status = Pass
==============
=============== End of Requirement 4.5-1 ===============
04 01 2021; 12:37:16PM Project Data Saved To File
04 01 2021; 12:37:21PM Requirement 4.5-2:  Compliant
=============== End of Requirement 4.5-2 ===============
04 01 2021; 12:37:35PM Processing Requirement 4.6   Return Status :  Passed
==============
Project Data
==============
**INPUT**
      Space Structure Name = GEARRS-3
      Space Structure Type = Payload
      Perigee Altitude = 500.000000 (km)
      Apogee Altitude = 500.000000 (km)
      Inclination = 45.000000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Area-To-Mass Ratio = 0.002840 (m^2/kg)
      Start Year = 2021.000000 (yr)
      Initial Mass = 3.171000 (kg)
      Final Mass = 3.171000 (kg)
      Duration = 2.000000 (yr)
      Station Kept = False
```

```
      Abandoned = True
      PMD Perigee Altitude = 488.187759 (km)
      PMD Apogee Altitude = 507.154754 (km)
      PMD Inclination = 45.000128 (deg)
      PMD RAAN = 358.009748 (deg)
      PMD Argument of Perigee = 121.344673 (deg)
      PMD Mean Anomaly = 0.000000 (deg)
**OUTPUT**
      Suggested Perigee Altitude = 488.187759 (km)
      Suggested Apogee Altitude = 507.154754 (km)
      Returned Error Message = Passes LEO reentry orbit criteria.
      Released Year = 2036 (yr)
      Requirement = 61
      Compliance Status = Pass
==============
=============== End of Requirement 4.6 ===============
04 01 2021; 12:37:35PM *********Processing Requirement 4.7-1
      Return Status :  Passed
***********INPUT****
 Item Number = 1
name = GEARRS-3
quantity = 1
parent = 0
materialID = 8
type = Box
Aero Mass = 3.171000
Thermal Mass = 3.171000
Diameter/Width = 0.100000
Length = 0.290000
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 = 0.290000
name = NSL Duplex Antenna
quantity = 2
parent = 1
materialID = 40
type = Box
Aero Mass = 0.069000
Thermal Mass = 0.069000
Diameter/Width = 0.050000
Length = 0.050000
Height = 0.012500
name = NSL Simplex Antenna
```

```
quantity = 2
parent = 1
materialID = 40
type = Box
Aero Mass = 0.015000
Thermal Mass = 0.015000
Diameter/Width = 0.035000
Length = 0.035000
Height = 0.005000
name = NSL RBF Switch Assembly
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.005000
Thermal Mass = 0.005000
Diameter/Width = 0.010000
Length = 0.040000
Height = 0.005000
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 = 0.004500
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 = 0.002500
name = NSL Lipo Battery UL 925050 Single
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.044000
Thermal Mass = 0.044000
Diameter/Width = 0.050000
Length = 0.055000
Height = 0.007000
name = NSL BlackBOX Patch Frame
```

```
quantity = 1
parent = 1
materialID = 5
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 = 8
parent = 1
materialID = 5
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 = 52
type = Cylinder
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.003500
Length = 1.000000
name = Fasteners
quantity = 20
parent = 1
materialID = 54
type = Box
Aero Mass = 0.003250
Thermal Mass = 0.003250
Diameter/Width = 0.007000
Length = 0.012500
Height = 0.007000
name = NSL D2F Duplex Module
quantity = 1
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.060000
Thermal Mass = 0.060000
Diameter/Width = 0.060000
Length = 0.118000
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 = 0.014000
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 = Box
Aero Mass = 0.009000
Thermal Mass = 0.009000
Diameter/Width = 0.020000
Length = 0.050000
Height = 0.005000
name = NSL Entergetic Partical Detector
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 Particle Detector
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.003000
Thermal Mass = 0.003000
Diameter/Width = 0.015000
Length = 0.032000
Height = 0.005000
**************OUTPUT****
Item Number = 1
name = GEARRS-3
Demise Altitude = 77.993660
Debris Casualty Area = 0.000000
```

```
Impact Kinetic Energy = 0.000000
************************************
name = NSL 3U CubeSat Chassis
Demise Altitude = 72.762589
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = NSL 3x1 Deploy Solar Array
Demise Altitude = 77.144531
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = NSL Duplex Antenna
Demise Altitude = 73.483765
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = NSL Simplex Antenna
Demise Altitude = 75.923767
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = NSL RBF Switch Assembly
Demise Altitude = 76.884285
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = Rail Switches
Demise Altitude = 0.000000
Debris Casualty Area = 1.503264
Impact Kinetic Energy = 0.276815
************************************
name = NSL BlackBOX Patch Antenna
Demise Altitude = 76.362770
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = NSL BlackBOX Patch PCB
Demise Altitude = 77.388420
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = NSL Lipo Battery UL 925050 Single
Demise Altitude = 75.196655
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = NSL BlackBOX Patch Frame
Demise Altitude = 77.758202
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = NSL EPS / COMM
Demise Altitude = 75.746124
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = NSL Dual Lipo Battery Pack UL 925050 Tenergy
Demise Altitude = 73.815239
Debris Casualty Area = 0.000000
```

```
Impact Kinetic Energy = 0.000000
************************************
name = Cabling
Demise Altitude = 77.424202
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = Fasteners
Demise Altitude = 74.050003
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = NSL D2F Duplex Module
Demise Altitude = 76.754822
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = NSL S2F Backup Simplex
Demise Altitude = 76.565781
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = NSL ADACS Coil
Demise Altitude = 75.254417
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = NSL ADACS Module
Demise Altitude = 77.566231
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = NSL Peak Power Tracker
Demise Altitude = 77.260178
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = NSL Entergetic Partical Detector
Demise Altitude = 77.285034
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = NSL Particle Detector
Demise Altitude = 77.556786
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
=============== End of Requirement 4.7-1 ===============
04 01 2021; 12:37:35PM Project Data Saved To File
04 01 2021; 12:38:06PM Science and Engineering - Orbit Lifetime/Dwell Time
**INPUT**
      Start Year = 2021.000000 (yr)
      Perigee Altitude = 500.000000 (km)
      Apogee Altitude = 500.000000 (km)
      Inclination = 45.000000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Area-To-Mass Ratio = 0.002840 (m^2/kg)
**OUTPUT**
      Orbital Lifetime from Startyr = 15.019849 (yr)
```

```
      Time Spent in LEO during Lifetime  = 15.019849 (yr)
      Last year of Propagation = 2036 (yr)
      Returned Error Message: Object reentered
04 01 2021; 12:38:44PM Science and Engineering - Apogee/Perigee History for a Given
Orbit
**INPUT**
      Perigee Altitude = 500.000000 (km)
      Apogee Altitude = 500.000000 (km)
      Inclination = 45.000000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Area-To-Mass Ratio = 0.002840 (m^2/kg)
      Start Year = 2021.600000 (yr)
      Integration Time = 16.000000 (yr)
**OUTPUT**
      Plot
04 01 2021; 12:48:54PM Project Data Saved To File
```