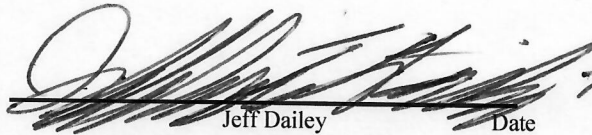


Orbital Debris Assessment Report

GEARRS-3

per NASA-STD 8719.14A

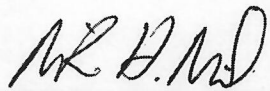
Signature Page

 7.17.2019

Jeff Dailey Date
CTO, Near Space Launch, Inc.

 7/17/19

Mike Miller Date
Licensing Coordinator, Sterk Solutions Corporation

 7/17/19

Michael H. Miller Date
Licensing Analyst, Sterk Solutions Corporation

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 Email: 6U CubeSat 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

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 TBD
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.

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 3.17 Kg. See Figure 1.

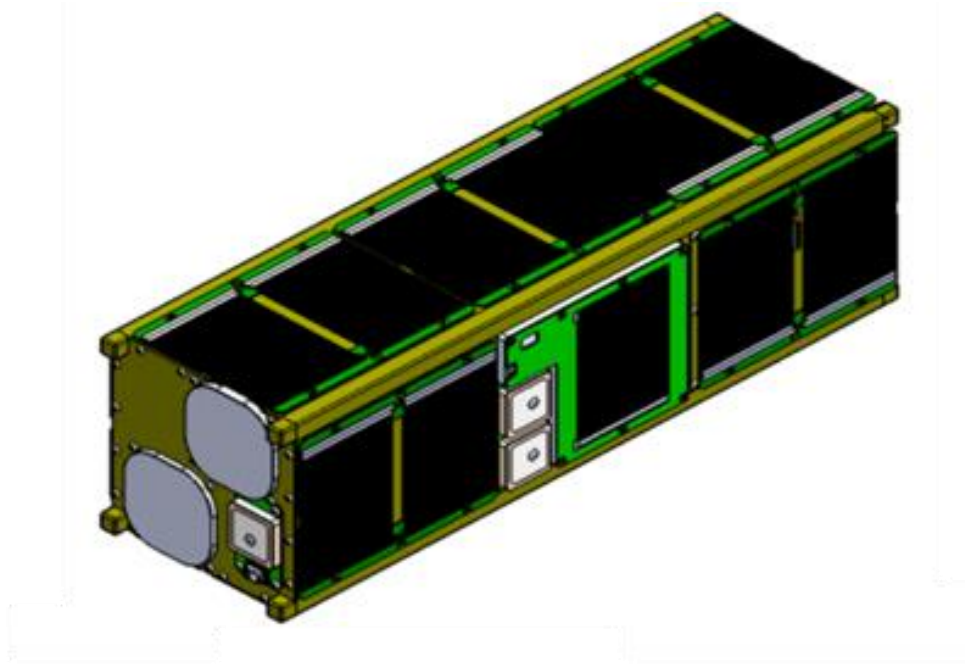


Figure 1 GEARRS-3 3U Cubesat

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 "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 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.

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 4.5-1.

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- 1. No systems are required. Requirements 4.6-2, 4.6-3 and 4.6-4 therefore are not applicable.

Summary of DAS 2.1.1 Orbital Lifetime Calculations:

DAS inputs are: 550 km circular orbit, with an inclination of 90° at deployment no earlier than August 2019. 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 m². From DAS, the lifetime for this maximum case will be 6.73 years.

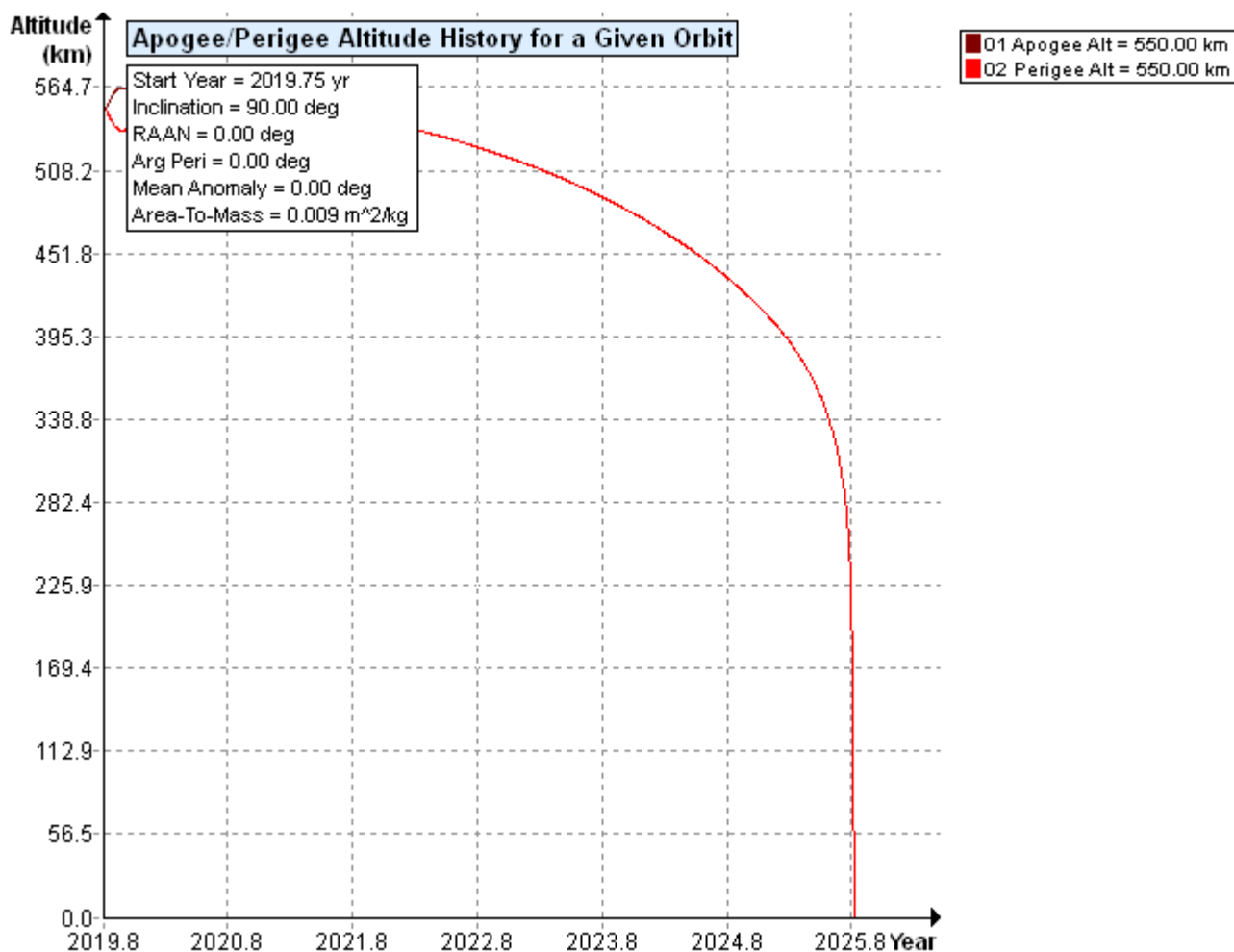


Figure 3 Altitude vs. Time GEARRS-3 Spacecraft

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 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 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.

All components TBD demise upon reentry and all 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

*****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
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Thermal Mass = 0.104000
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quantity = 2
parent = 1
materialID = 40
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Thermal Mass = 0.069000
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Length = 0.050000
Height = 0.012500
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quantity = 2
parent = 1
materialID = 40
type = Box
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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
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 Length = 0.020000
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 quantity = 2
 parent = 1
 materialID = 40
 type = Box
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 Length = 0.025000
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 quantity = 1
 parent = 1
 materialID = 23
 type = Box
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 Thermal Mass = 0.031000
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 Length = 0.100000
 Height = 0.002500
 name = NSL Lipo Battery UL 925050 Single
 quantity = 1
 parent = 1
 materialID = 5
 type = Box
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 type = Box
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 Diameter/Width = 0.082000
 Length = 0.100000
 Height = 0.005000
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 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
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 Thermal Mass = 0.083000
 Diameter/Width = 0.050000
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 parent = 1
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 Diameter/Width = 0.003500
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 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
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 quantity = 1
 parent = 1
 materialID = 23
 type = Flat Plate
 Aero Mass = 0.060000
 Thermal Mass = 0.060000
 Diameter/Width = 0.060000
 Length = 0.118000
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 quantity = 2
 parent = 1
 materialID = 23
 type = Box
 Aero Mass = 0.056000
 Thermal Mass = 0.056000
 Diameter/Width = 0.045000
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 type = Cylinder
 Aero Mass = 0.030000
 Thermal Mass = 0.030000
 Diameter/Width = 0.008000

```

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quantity = 1
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Thermal Mass = 0.010000
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Length = 0.070000
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quantity = 2
parent = 1
materialID = 23
type = Box
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Thermal Mass = 0.009000
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Length = 0.050000
Height = 0.005000
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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
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Thermal Mass = 0.003000
Diameter/Width = 0.015000
Length = 0.032000
Height = 0.005000
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Demise Altitude = 77.995102
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
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name = NSL 3U CubeSat Chassis
Demise Altitude = 73.424583
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
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name = NSL 3x1 Deploy Solar Array
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name = NSL Duplex Antenna
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name = NSL RBF Switch Assembly
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Demise Altitude = 77.802185
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
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name = NSL EPS / COMM
Demise Altitude = 76.056259
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name = NSL Dual Lipo Battery Pack UL 925050 Tenergy
Demise Altitude = 74.347290
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name = Cabling
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Impact Kinetic Energy = 0.000000
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name = Fasteners
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Debris Casualty Area = 0.000000

```

```

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name = NSL ADACS Coil
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name = NSL ADACS Module
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name = NSL Peak Power Tracker
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Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
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name = NSL Entergetic Partical Detector
Demise Altitude = 77.383278
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
*****
name = NSL Particle Detector
Demise Altitude = 77.616867
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
*****

```

****INPUT****

```

Space Structure Name = GEARRS-3
Space Structure Type = Payload
Perigee Altitude = 550.000000 (km)
Apogee Altitude = 550.000000 (km)
Inclination = 90.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.009000 (m^2/kg)
Start Year = 2019.000000 (yr)
Initial Mass = 3.171000 (kg)
Final Mass = 3.171000 (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
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Date Range Error Message: Normal Date Range
Status = Pass

=====

===== End of Requirement 4.5-1 =====

07 16 2019; 15:52:50PM Requirement 4.5-2: Compliant

07 16 2019; 15:52:54PM Processing Requirement 4.6 Return Status : Passed

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