2013

ArduSat-2X Orbital Debris Assessment Report

NANOSATISFI MARKET STUDY GENERIC MISSION PROFILE

PREPARED BY: NANOSATISFI INC

Summarized List of Compliance Status to Orbital Debris Requirements

For convenience, below is a summarized list of the compliance status to orbital debris requirements. Detailed explanations for each of these compliance statements are available in ODAR Sections 1 through 8.

4.3-1, Mission-Related Debris Passing Through LEO:	COMPLIANT
4.3-2, Mission-Related Debris Passing Near GEO	COMPLIANT
4.4-1, Limiting the risk to other space systems from accidental explosions during deployment and mission operations while in orbit about Earth or the Moon:	COMPLIANT
4.4-2, Design for passivation after completion of mission operations while in orbit about Earth or the Moon:	N/A
4.4-3, Limiting the long-term risk to other space systems from planned breakups:	COMPLIANT
4.4-4, Limiting the short-term risk to other space systems from planned breakups:	COMPLIANT
4.5-1, Probability of Collision with Large Objects:	COMPLIANT
4.5-2, Probability of Damage from Small Objects:	COMPLIANT
4.6-1, Disposal for space structures passing through LEO:	COMPLIANT
4.6-2, Disposal for space structures passing through GEO:	N/A
4.6-3, Disposal for space structures between LEO and GEO:	N/A
4.6-4, Reliability of postmission disposal operations:	N/A
4.8-1, Collision Hazards of Space Tethers	N/A

ODAR Section 1: Program Management and Mission Overview

Program / Project Manager	Peter Platzer
Mission Description	The purpose of the ForeSight CubeSat market study is to evaluate the commercial viability of a low-Earth orbiting constellation of nanosatellites providing both a platform for high school STEM education and for generating high-revisit Earth observation data. As a part of this study, NanoSatisfi will be launching the ArduSat-2 and ArduSat-2X satellites to perform technology demonstration of several spacecraft modules required for the constellation; a separate ODAR report has been prepared for the ArduSat-2 mission. The purpose of this ODAR is to demonstrate compliance of the rest of the constellation, which will cover a range of orbits with a generic satellite form factor, the ArduSat-2X, described in ODAR Section 2.
Project Milestones:	• The development of ArduSat-2 began in Spring 2013, following the delivery of ArduSat-1 and ArduSat-X to their launch provider. The detailed design of ArduSat-2 was completed in Summer 2013, and is currently undergoing Phase C/D manufacturing / integration in San Francisco. • ArduSat-2 will be delivered to NanoRacks LLC, NanoSatisfi's launch service provider POC, in November 2013. ArduSat-2 is manifested to be launched on the ORB-1 ISS resupply mission in December 2013, and deployed from ISS into its operational orbit in early 2014. • The remainder of the market study will be performed beginning in 2014, and will conclude at the end of 2015.
Foreign Government Involvement	None
Proposed Launch Date:	December 5, 2013 (ArduSat-2) Follow-on satellites beginning Q1 2014 (including both ArduSat-2s and ArduSat-2Xs)
Proposed Launch Vehicle:	Antares (Cygnus), ORB-1 ISS resupply mission
Proposed Launch Site:	Wallops
Launch Vehicle Operator:	Orbital Sciences
Mission Duration:	Dec 2013 – Dec 2015
Launch / Deployment Profile:	The generic mission profile for each of the satellites in the market study is divided into four segments: launch & pre-deployment, TX Inhibit, operations, and postmission disposal.

	Launch & Pre-Deployment The nanosatellites in the study are launched either as secondary payloads on an existing mission, or as cargo during a resupply mission to the International Space Station. During launch (and in the case of ISS deployment, during handling inside the station), the satellites maintain an unpowered state using three independent inhibits detailed in "Launch Inhibits" below. The launch & pre-deployment phase continues from launch until the satellite is deployed from the ISS / primary launch vehicle into a separate free-flying orbit. **TX Inhibit** The TX inhibit phase of the mission begins upon deployment of the satellite from the vehicle / ISS, whereupon the three inhibit switches release, powering on the satellite and starting a "TX Inhibit" timer, the duration of which is specified by the launch provider (typically 45 minutes). Immediately following complete deployment, a UHF turnstile antenna is deployed. While the timer is active, the satellite does not transmit with either its UHF or S-Band transmitter. The post-deployment phase of the mission ends at the completion of the TX Inhibit timer. **Operations** The operational phase of the satellite begins following the completion of the TX Inhibit timer, and continues until the end of the market study, or the satellite passively reenters the atmosphere and disintegrates. During the operational phase, once contact has been established with the satellite by one of NanoSatisfi's ground stations, an active "VHF Deploy" command is transmitted from the ground, to instruct the satellite to deploy the two orthogonal VHF monopole antennae. The orbital lifetime of the satellites is highly dependent on the deployment altitude. For satellites deployed above 500km, a drag device will be deployed at the beginning of the operational phase of the mission, in order to comply with the required 25-year maximum on-orbit lifetime. **Postmission Disposal** For satellites at a higher altitude, the satellites will continue to naturally decay beyond the two-year mission of the market study. If authorization is not obtained at the end of the market analysis to continue operation of the satellites still on-orbit, the satellites deactivated (including all onboard transmitters), and allowed to decay until they disintegrate in the upper atmosphere
Selection of Orbit:	The selection of the ISS orbit was made due to available launch opportunities and a lack of onboard propulsion systems.
Potential Physical Interference with Other Orbiting Object:	As the satellites do not have active propulsion systems, their orbits will naturally decay following deployment from the launch vehicle. As detailed in Section 5, the probability of physical interference between the satellites and other space objects is sufficiently unlikely that the satellite complies with Requirement 4.5.

ODAR Section 2: Spacecraft Description

Physical Description:

Property	Value
Total Mass at Launch	4kg
Dry Mass at Launch	4kg
Form Factor	3U CubeSat
COG	<3cm radius from geometric centre
Envelope (stowed)	100mm x 100mm x 340.5mm (excluding dynamic envelope)
Envelope (deployed)	670mm x 670mm x 500mm
Propulsion Systems	None
Fluid Systems	None
AOCS	Stabilization/pointing with 3x orthogonal reaction wheels, desaturation + coarse poinging with magnetotorquers
Range Safety / Pyrotechnic Devices	None
Electrical Generation	Triple-junction GaAs solar panels
Electrical Storage	Rechargable lithium-ion battery pack
Radioactive Materials	None

ODAR Section 3: Assessment of Debris Released During Normal Operations

Objects larger than 1mm expected to be released during orbit:	**None**
Rationale for release of each object:	N/A
Time of release of each object:	N/A
Release velocity of each object:	N/A
Expected orbital parameters of each object:	N/A
Calculated orbital lifetime of each object:	N/A

Assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2:	
4.3-1, Mission-Related Debris Passing Through LEO:	**COMPLIANT**
4.3-2, Mission-Related Debris Passing Near GEO:	**COMPLIANT**

A DAS 2.0.2 log demonstrating the compliance to the above requirements is available in Appendix A – “DAS 2.0.2 Log”.

ODAR Section 4: Assessment of Spacecraft Intentional Breakups and Potential for Explosions

Potential causes for spacecraft breakup:

There are only two plausible causes for breakup of the satellites:

- energy released from onboard batteries, and
- mechanical failure of the reaction wheels

Summary of failure modes and effects analysis of all credible failure modes which may lead to an accidental explosion:

The batteries aboard the satellites are 2600mAh Lithium-Ion cells, and represent the only credible failure mode during which stored energy is released. The main failure modes associated with Lithium Ion batteries result from overcharging, overdischarging, internal shorts, and external shorts.

The battery pack onboard ArduSat-2 and the ArduSat-2X is in compliance with NASA's Crewed Space Vehicle Battery Safety Requirements (JSC-20793), and complies with all controls / process requirements identified in JSC-20793 Section 5.4.3 to mitigate chance of any accidental venting / explosion caused by the above failure modes.

The only failure mode of the reaction wheel assemblies that could lead to creation of debris would be breakup of the wheels themselves due to mechanical failure while operating at a high angular rate. Risk mitigation strategies for breakups due to the reaction wheels, including limiting the maximum rotational speed of the wheels and containing them within a sealed compartment.

Detailed Plan for any designed spacecraft breakup, including explosions and intentional collisions:

There is no planned breakup the satellites on-orbit.

List of components passivated at EOM:

At the end of mission, the only components that will require passivation are the reaction wheels. At the end of the mission, the reaction wheels will be de-spun to passivate.

Rationale for all items required to be passivated that can not be due to design:

N/A

Assessment of spacecraft compliance with Requirements 4.4-1 through 4.4-4:	
4.4-1, Limiting the risk to other space systems from accidental explosions during deployment and mission operations while in orbit about Earth or the Moon	**COMPLIANT**
4.4-2, Design for passivation after completion of mission operations while in orbit about Earth or the Moon	**COMPLIANT**

4.4-3, Limiting the long-term risk to other space systems from planned breakups: There are no planned breakups of any of the satellites.	**COMPLIANT**
4.4-4, Limiting the short-term risk to other space systems from planned breakups There are no planned breakups of any of the satellites.	**COMPLIANT**

ODAR Section 5: Assessment of Spacecraft Potential for On-Orbit Collisions

Probability for Collision with Objects >10cm:

The probability of a collision of any of the satellites with an orbiting object larger than 10cm in diameter was sufficiently small that the simulation performed using DAS 2.0.2 software returned a probability value of 0.

Assessment of spacecraft compliance with Requirement 4.5-1 and 4.5-2:	
4.5-1, Probability of Collision with Large Objects:	**COMPLIANT**
4.5-2, Probability of Damage from Small Objects:	**COMPLIANT**

A DAS 2.0.2 log demonstrating the compliance to the above requirements is available in Appendix A – “DAS 2.0.2 Log”.

ODAR Section 6: Assessment of Spacecraft Postmission Disposal Plans and Procedures

Description of Disposal Option Selected:

Following its deployment from the ISS, the satellites orbits will naturally decay until they reenters the atmosphere. As detailed in Section 7, the satellites will completely disintegrate during reentry, with no components surviving reentry to the ground.

For satellites deployed above a threshold altitude, a drag device will be deployed to ensure that all satellites passively reenter the atmosphere in under 25 years.

Identification of Systems Required for Postmission Disposal: Drag device (for select satellties)

Plan for Spacecraft Maneuvers required for Postmission Disposal: N/A

Calculation of final Area-to-Mass Ratio if Atmospheric Reentry Not Selected: N/A

Assessment of Spacecraft Compliance with Requirements 4.6-1 through 4.6-4:	
4.6-1, Disposal for space structures passing through LEO All of the satellites will reenter the atmosphere within 25 years of mission completion and 30 years of launch.	**COMPLIANT**
4.6-2, Disposal for space structures passing through GEO:	**N/A**
4.6-3, Disposal for space structures between LEO and GEO:	**N/A**
4.6-4, Reliability of postmission disposal operations:	**COMPLIANT**

ODAR Section 7: Assessment of Spacecraft Reentry Hazards

Detailed description of spacecraft components by size, mass, material, shape, and original location on the space vehicle:

A system-level mass breakdown and primary materials list included in the generic satellite bus is available in the table below:

Subsystem	Materials	Quantity	Mass (g)	Shape	Size (mm)
Solar Panels	Glass, GaAs, FR4 PCB	13	59	Flat Plate	80 x 100
GPS Patch Antenna	Aluminum	1	50	Box	40 x 40 x 20
Subsystem PCBs	FR4 PCB	16	100	Flat Plate	90 x 90
Primary Structure	Aluminum	1	600	Box	100 x 100 x 227
VHF Antenna Deployer	Aluminum, FR4 PCB	2	50	Box	40 x 70 x 10
Payload Mounting Plate	Aluminum	1	100	Plate	90 x 90
S-Band Patch Antenna	Aluminum	1	50	Box	40 x 40 x 20
S-Band Amplifier	Aluminum, FR4 PCB	1	20	Box	40 x 20 x 8
NIR Camera	Aluminum, FR4 PCB, Glass	1	40	Box	40 x 40 x 30
Optical Camera	Aluminum, FR4 PCB, Glass	1	40	Box	50 x 30 x 20
Geiger Counter	Ferrite, FR4 PCB	1	30	Box	30 x 30 x 20
Reaction wheel assembly + enclosure	Aluminum, copper, FR4 PCB	1	400	Box	80 x 80 x 40

Summary of objects expected to survive an uncontrolled reentry (using DAS 2.0.2 software): None

Calculation of probability of human casualty for expected reentry year and inclination: 0%

Assessment of spacecraft compliance with Requirement 4.7-1:	

4.7-1, Casualty Risk from Reentry Debris:	**COMPLIANT**

A DAS 2.0.2 log demonstrating the compliance to Requirement 4.7-1 is available in Appendix A – “DAS 2.0.2 Log”.

ODAR Section 7A: Assessment of Spacecraft Hazardous Materials

Summary of Hazardous Materials Contained on Spacecraft: None

ODAR Section 8: Assessment for Tether Missions

Type of tether: N/A

Description of tether system: N/A

Determination of minimum size of object that will cause the tether to be severed: N/A

Tether mission plan, including duration and postmission disposal: N/A

Probability of tether colliding with large space objects: N/A

Probability of tether being severed during mission or after postmission disposal: N/A

Maximum orbital lifetime of a severed tether fragment: N/A

Assessment of compliance with Requirement 4.8-1:	
4.8-1, Collision Hazards of Space Tethers:	**N/A**

Appendix A: DAS 2.0.2 Log

Below is the log of an assessment performed on the worst-case scenario mission profile expected during the market study, which is a satellite that remains on orbit for 20 years, gradually deorbiting without a drag device.

```
08 02 2013; 11:57:09AM     DAS Application Started
08 02 2013; 11:57:11AM     Opened Project C:\Program Files
(x86)\NASA\DAS 2.0\ArduSat2\
08 02 2013; 11:57:19AM     Opened Project C:\Program Files
(x86)\NASA\DAS 2.0\ForeSight-Generic\
08 02 2013; 11:58:02AM     Project Data Saved To File
08 02 2013; 11:58:03AM     Mission Editor Changes Applied
08 02 2013; 11:58:06AM     Project Data Saved To File
08 02 2013; 11:58:44AM     Project Data Saved To File
08 02 2013; 12:00:00PM     Project Data Saved To File
08 02 2013; 12:03:16PM     Project Data Saved To File
08 02 2013; 12:03:40PM     Processing Requirement 4.6 Return Status :
Passed

==============
Project Data
==============

**INPUT**

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

     Perigee Altitude = 500.000000 (km)
     Apogee Altitude = 500.000000 (km)
     Inclination = 51.600000 (deg)
     RAAN = 0.000000 (deg)
     Argument of Perigee = 0.000000 (deg)
     Mean Anomaly = 0.000000 (deg)
     Area-To-Mass Ratio = 0.003800 (m^2/kg)
     Start Year = 2014.000000 (yr)
     Initial Mass = 4.000000 (kg)
     Final Mass = 4.000000 (kg)
     Duration = 20.000000 (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 = 500.000000 (km)
```

```
      Suggested Apogee Altitude = 500.000000 (km)
      Returned Error Message = Reentry during mission (no PMD req.).

      Released Year = 2023 (yr)
      Requirement = 61
      Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
08 02 2013; 12:03:40PM     *********Processing Requirement 4.7-1
      Return Status :  Passed

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

name = ForeSight-1
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 4.000000
Thermal Mass = 4.000000
Diameter/Width = 0.100000
Length = 0.300000
Height = 0.100000

name = Structure
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.600000
Thermal Mass = 0.600000
Diameter/Width = 0.100000
Length = 0.300000
Height = 0.100000

name = Batteries
quantity = 4
parent = 1
materialID = 5
type = Cylinder
Aero Mass = 0.060000
Thermal Mass = 0.060000
Diameter/Width = 0.020000
Length = 0.080000

name = Solar Panels
quantity = 13
parent = 1
materialID = 24
```

type = Flat Plate
Aero Mass = 0.059000
Thermal Mass = 0.059000
Diameter/Width = 0.100000
Length = 0.100000

name = PCB Stack
quantity = 16
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.100000
Length = 0.100000

name = VHF Deployer
quantity = 2
parent = 1
materialID = 5
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.050000
Length = 0.070000
Height = 0.010000

name = Patch Antennae
quantity = 2
parent = 1
materialID = 5
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.040000
Length = 0.040000
Height = 0.030000

name = Reaction Wheel Assembly
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.300000
Thermal Mass = 0.300000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.040000

name = Optical Payload
quantity = 1
parent = 1

```
materialID = 5
type = Cylinder
Aero Mass = 0.200000
Thermal Mass = 0.200000
Diameter/Width = 0.035000
Length = 0.080000

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

name = ForeSight-1
Demise Altitude = 77.999301
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Structure
Demise Altitude = 75.445800
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Batteries
Demise Altitude = 74.760652
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Solar Panels
Demise Altitude = 77.552879
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = PCB Stack
Demise Altitude = 76.422785
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = VHF Deployer
Demise Altitude = 75.876621
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Patch Antennae
Demise Altitude = 75.328441
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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

```
name = Reaction Wheel Assembly
Demise Altitude = 73.223496
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Optical Payload
Demise Altitude = 71.291597
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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

=============== End of Requirement 4.7-1 ===============
08 02 2013; 12:03:42PM     Project Data Saved To File
08 02 2013; 12:04:26PM     Processing Requirement 4.3-1:    Return
Status :  Not Run

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

=============== End of Requirement 4.3-1 ===============
08 02 2013; 12:04:31PM     Processing Requirement 4.3-2: Return Status
: Passed

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

=============== End of Requirement 4.3-2 ===============
08 02 2013; 12:04:34PM     Requirement 4.4-3:  Compliant

=============== End of Requirement 4.4-3 ===============
08 02 2013; 12:04:36PM     Requirement 4.4-3:  Compliant

=============== End of Requirement 4.4-3 ===============
08 02 2013; 12:04:42PM     Processing Requirement 4.5-1:    Return
Status :  Passed

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

**INPUT**

      Space Structure Name = ForeSight-1
      Space Structure Type = Payload
      Perigee Altitude = 500.000000 (km)
      Apogee Altitude = 500.000000 (km)
      Inclination = 51.600000 (deg)
      RAAN = 0.000000 (deg)
```

Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.003800 (m^2/kg)
Start Year = 2014.000000 (yr)
Initial Mass = 4.000000 (kg)
Final Mass = 4.000000 (kg)
Duration = 20.000000 (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 ==========
08 02 2013; 12:04:49PM Requirement 4.5-2: Compliant
08 02 2013; 12:04:50PM Processing Requirement 4.6 Return Status : Passed

==========
Project Data
==========

INPUT

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

Perigee Altitude = 500.000000 (km)
Apogee Altitude = 500.000000 (km)
Inclination = 51.600000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.003800 (m^2/kg)
Start Year = 2014.000000 (yr)
Initial Mass = 4.000000 (kg)
Final Mass = 4.000000 (kg)
Duration = 20.000000 (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 = 500.000000 (km)
      Suggested Apogee Altitude = 500.000000 (km)
      Returned Error Message = Reentry during mission (no PMD req.).

      Released Year = 2023 (yr)
      Requirement = 61
      Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
08 02 2013; 12:05:11PM     *********Processing Requirement 4.7-1
      Return Status :  Passed

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

name = ForeSight-1
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 4.000000
Thermal Mass = 4.000000
Diameter/Width = 0.100000
Length = 0.300000
Height = 0.100000

name = Structure
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.600000
Thermal Mass = 0.600000
Diameter/Width = 0.100000
Length = 0.300000
Height = 0.100000

name = Batteries
quantity = 4
parent = 1
materialID = 5
```

type = Cylinder
Aero Mass = 0.060000
Thermal Mass = 0.060000
Diameter/Width = 0.020000
Length = 0.080000

name = Solar Panels
quantity = 13
parent = 1
materialID = 24
type = Flat Plate
Aero Mass = 0.059000
Thermal Mass = 0.059000
Diameter/Width = 0.100000
Length = 0.100000

name = PCB Stack
quantity = 16
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.100000
Length = 0.100000

name = VHF Deployer
quantity = 2
parent = 1
materialID = 5
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.050000
Length = 0.070000
Height = 0.010000

name = Patch Antennae
quantity = 2
parent = 1
materialID = 5
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.040000
Length = 0.040000
Height = 0.030000

name = Reaction Wheel Assembly
quantity = 1
parent = 1
materialID = 5

```
type = Box
Aero Mass = 0.300000
Thermal Mass = 0.300000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.040000

name = Optical Payload
quantity = 1
parent = 1
materialID = 5
type = Cylinder
Aero Mass = 0.200000
Thermal Mass = 0.200000
Diameter/Width = 0.035000
Length = 0.080000

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

name = ForeSight-1
Demise Altitude = 77.999301
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Structure
Demise Altitude = 75.445800
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Batteries
Demise Altitude = 74.760652
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Solar Panels
Demise Altitude = 77.552879
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = PCB Stack
Demise Altitude = 76.422785
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = VHF Deployer
Demise Altitude = 75.876621
```

Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = Patch Antennae
Demise Altitude = 75.328441
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = Reaction Wheel Assembly
Demise Altitude = 73.223496
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = Optical Payload
Demise Altitude = 71.291597
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

========== End of Requirement 4.7-1 ==========