OSNSAT-1 Orbital Debris Assessment Report (ODAR)

In accordance with NPR 8715.6A, this report is presented as compliance with the required reporting format per NASA-STD-8719.14, APPENDIX A.

Report Version: A (6/6/2016)

DAS Software Used in This Analysis: DAS v2.0.2

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Assessment Report Format:
ODAR Technical Sections Format Requirements:
This ODAR follows the format in NASA-STD-8719.14, Appendix A.1 and includes the content indicated at a minimum in each section 2 through 8 below for the OSNSat-1 satellite. Sections 9 through 14 apply to the launch vehicle ODAR and are not covered here.

The following table summarizes the compliance status of the OSNSAT-1 mission. The OSNSAT-1 mission 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 Minimal risk to orbital environment, mitigated by orbital lifetime.
4.4-2 Compliant Minimal risk to orbital environment, mitigated by orbital lifetime.
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 6.96 months
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 release under OSNSat-1 mission

Mission Description:
Open Space Networks Satellite 1 (OSNSat) is a lightweight prototype satellite to evaluate spread spectrum communications in the 900 MHz ISM band. OSNSat is a tubesat weighing approximately .75 Kg built, owned and operated by OpenSpace Networks, a California corporation. OSNSat will be packaged, along with another tubesat in a Tubesat PicoSatellite Orbital Deployer (TuPOD). This second tubesat and the TuPOD are both built and operated by an entity other

than OSN. The TuPOD containing both tubesats will be carried on a Japanese Space Agency re-supply mission to the ISS, expected to be launched approximately October 1, 2016.

The TuPOD will be ejected from the ISS subsequent to its arrival there. The TuPOD will drift for three days to gain separation from the ISS, after which time both tubesats will be deployed using a spring mechanism contained in the deployer.

OSNSat has no propulsion system, and no solar cells. It is powered by ten primary lithium ion batteries approved for use on the ISS. OSNSat has two system components: a payload consisting of an Arduino micro controller managing a smart spread spectrum digital radio, and an Arduino micro controller based ground station to manage a ground based smart spread spectrum digital radio and the bidirectional communications with the OSNSat-1 payload and to subsequently record and store the results of these measurements. All hardware in both the satellite and ground station are Commercial Off The Shelf parts.

The OSNSat transceiver will be in acquisition mode, unless and until it receives a beacon from one of the three OSN base stations, and will then only transmit while over the United States and in range of a base station. The OSNSat-1 software (in both payload and ground station) will manage the sequence of measurements to evaluate the communications link during each orbit pass and will manage a shutdown protocol in the payload to minimize battery consumption between communications windows.

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This system will allow OSNSat-1 to be launched at a velocity of 0.5 m/sec from Tu-POD in a circular orbit initially approximately 300 or 400 km relative to Earth's surface after 3.5 days from deployment from ISS.

The OSNSat-1 orbit is defined as follows:
Apogee:404 km
Perigee: 402 km
Inclination: 51.64 degree

OSNSat-1 has no propulsion and therefore does not actively change orbits. OSNSat-1 will lose altitude, then slow down due to atmospheric friction and disintegrate on atmospheric re-entry between approximately 5 and 10 months after ISS deployment.

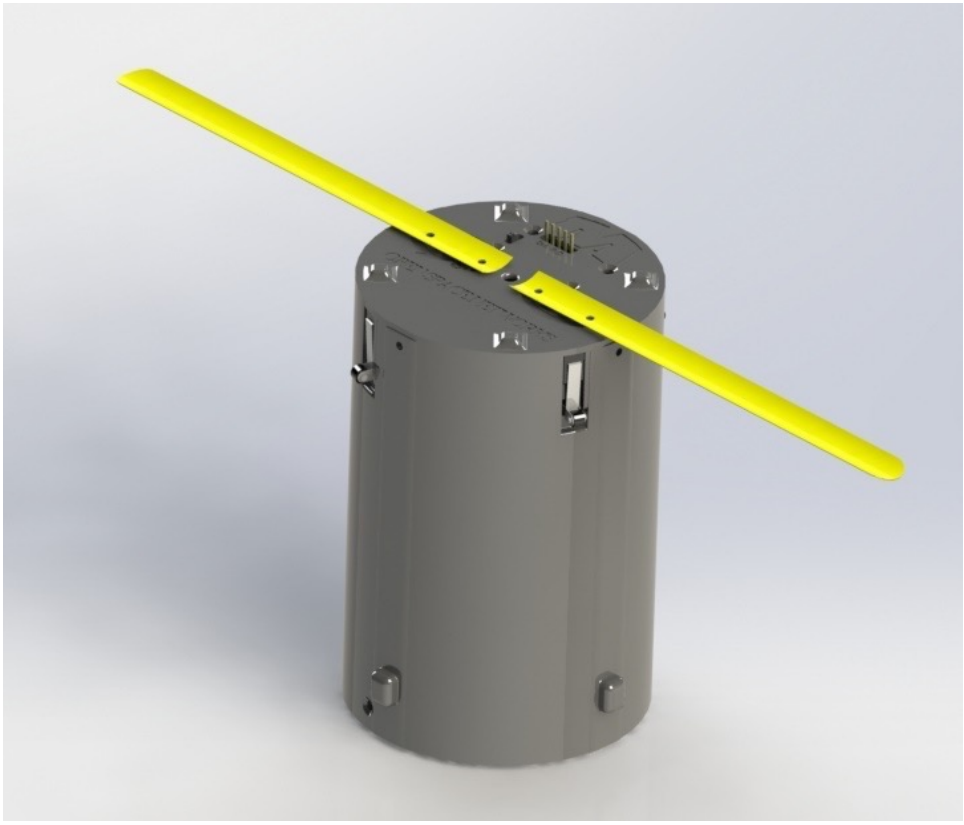


Figure 1: OSNSat-1 Full View with Antennas Deployed

ODAR Section 1: Program Management and Mission Overview

Program/project Manager: Ken Biba
Foreign government or space agency participation: JAXA - Japanese Space Agency
Summary of NASA's responsibility under the governing agreement(s): None

Physical description of the spacecraft:
Open Space Networks Satellite 1 (OSNSat) is a lightweight prototype satellite to evaluate spread spectrum communications in the 900 MHz ISM band. OSNSat is a tubesat weighing approximately .63 Kg built, owned and operated by OpenSpace Networks, a California corporation. OSNSat will be packaged, along with another tubesat in a Tubesat PicoSatellite Orbital Deployer (TuPOD). This second tubesat and the TuPOD are both built and operated by an entity other than OSN.

● An Arduino based logic board is the central processor of OSNSat-1.
● A LoRa compliant spread spectrum RFM-95 radio module manufactured by HopeRF will be the sole radio on board.
● The RF-95 will have a simple dipole antenna.
● The Arduino will execute a program both managing a low power sleep mode to maximize battery life, waking up when over the United States to listen for ground station radio beacons. While in contact with the ground station, a protocol to evaluate radio quality will performed. When out of range of the ground station, OSNSat-1 will return to a low power hibernation mode to preserve battery life.
● There are one voltage sensor to report battery voltage.

Total satellite mass at launch, including all propellants and fluids: 0.626 kg
Dry mass of satellite at launch, excluding solid rocket motor propellants: 0.626 kg

Description of all propulsion systems (cold gas, mono-propellant, bi-propellant, electric, nuclear): There will be no propulsion systems on OSNSat-1.

Identification, including mass and pressure, of all fluids (liquids and gases) planned to be on board and a description of the fluid loading plan or strategies, excluding fluids in sealed heat pipes.

Not applicable as there will be no fluids or gasses on board.

Fluids in Pressurized Batteries: None. OSNSat-1 uses unpressurized standard COTS Lithium battery cells.

Description of attitude control system and indication of the normal attitude of the spacecraft with respect to the velocity vector:

OSNSat-1 uses passive magnetic attitude control. The magnets are aligned along the length of the spacecraft so the spacecraft aligns with the Earth's magnetic field. This means that the satellite cross section presented to the direction of flight varies with location within the Earth's magnetic field as well as varying due to nutation (coning rotation). The variable tilt toward earth caused by local magnetic inclination should have little effect on orbit decay. Variable magnetic declination effects (angles away from true north) should average out with minimal or no effect.

Description of any range safety or other pyrotechnic devices: None

Description of the electrical generation and storage system: OSNSat-1 has no power generation. It uses power stored in 10 lithium batteries made by ULTRALIFE, part no. U9VLJP.
This battery is approved for flight on the ISS. The dimensions of each battery is 1.5 x 2.5 x 4.5cm and the weight is 36 g.

Identification of any other sources of stored energy not noted above: None.
Identification of any radioactive materials on board: None**.**

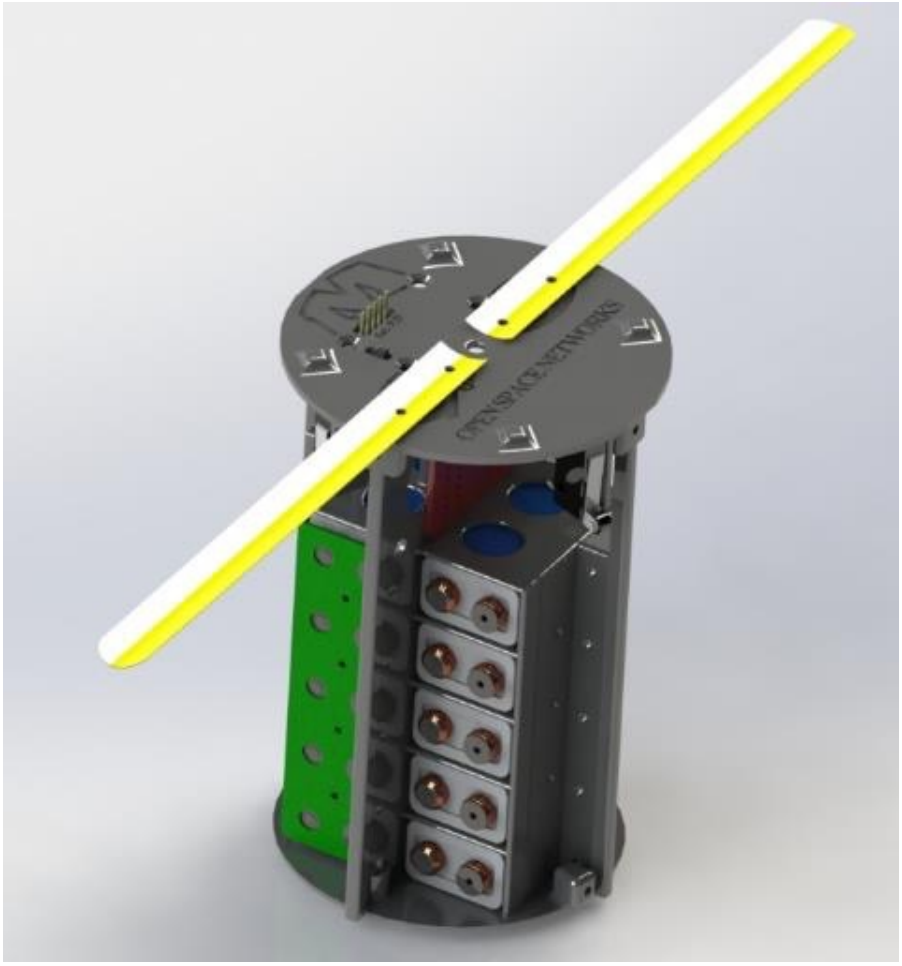


Figure 1: OSNSat-1 Full View with Antennas Deployed

ODAR Section 3: Assessment of Spacecraft Debris Released during Normal Operations

Identification of any object (>1 mm) expected to be released from the spacecraft any time after launch, including object dimensions, mass, and material: There are no intentional releases.
Rationale/necessity for release of each object: N/A.
Time of release of each object, relative to launch time: N/A.
Release velocity of each object with respect to spacecraft: N/A.
Expected orbital parameters (apogee, perigee, and inclination) of each object after release: N/A.
Calculated orbital lifetime of each object, including time spent in Low Earth Orbit (LEO): N/A.

Assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2 (per DAS v2.0)
4.3-1, Mission Related Debris Passing Through LEO: COMPLIANT
4.3-2, Mission Related Debris Passing Near GEO: COMPLIANT

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

Potential causes of spacecraft breakup during deployment and mission operations:
There is no credible scenario that would result in spacecraft breakup during normal deployment and operations.

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

To prevent in-mission failure of a battery cell, electric diodes have been placed for each battery cell to prevent over discharge and to disconnect the battery cells from the battery pack. Since there is no charging of the batteries there is no risk of over-charging and overheating.

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

We computed the probability of spacecraft collision with space objects larger than 10 cm in diameter during the orbital lifetime of the spacecraft (assumptions: 404 km altitude, 51.64° inclina-

tion, 0.001 m2 area), using the DAS 2.0.2 software, is 0.000.

Assessment of spacecraft compliance with Requirements 4.5-1 and 4.5-2 (per DAS v2.0, and calculation methods provided in NASA-STD-8719.14, section 4.5.4):

- ***Requirement 4.5-1. Limiting debris generated by collisions with large objects when operating in Earth orbit:*** For each spacecraft and launch vehicle orbital stage in or passing through LEO, the program or project shall demonstrate that, during the orbital lifetime of each spacecraft and orbital stage, the probability of accidental collision with space objects larger than 10 cm in diameter is less than 0.001 (Requirement 56506).

  Large Object Impact and Debris Generation Probability: 0.000; COMPLIANT.

- ***Requirement 4.5-2. Limiting debris generated by collisions with small objects when operating in Earth or lunar orbit:*** For each spacecraft, the program or project shall demonstrate that, during the mission of the spacecraft, the probability of accidental collision with orbital debris and meteoroids sufficient to prevent compliance with the applicable postmission disposal requirements is less than 0.01 (Requirement 56507).

  Small Object Impact and Debris Generation Probability: 0.000; COMPLIANT

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

6.1 Description of spacecraft disposal option selected:

OSNSat has no propulsion system. It will reenter passively due to atmospheric drag and be completely consumed in the atmosphere within 7 months.

6.2 Plan for any spacecraft maneuvers required to accomplish post-mission disposal:

No spacecraft maneuvers are required to accomplish post-mission disposal.

6.3 Calculation of area-to-mass ratio after postmission disposal, if the controlled reentry option is not selected:

Spacecraft Mass: 0.626 kg

Cross-sectional Area: 0.0099 m^2 (Calculated by DAS 2.0.2 for the configuration in Figure 1). **Area to mass ratio:** 0.00.012857 m^2 /kg

6.4 Assessment of spacecraft compliance with Requirements 4.6-1 through 4.6-5 (per DAS v 2.0 .2 and NASA-STD-8719.14 section):

Requirement 4.6-1. Disposal for space structures passing through LEO: A spacecraft or orbital stage with a perigee altitude below 2000 km shall be disposed of by one of three methods: (Requirement 56557)

Atmospheric reentry option:

- OSNSat-1 will be in an orbit in which natural forces will lead to atmospheric reentry within .7 year after launch.

Analysis:

05 11 2016; 01:37:50AM Processing Requirement 4.5-1: Return Status :Passed
==========
Run Data
==========
INPUT

Space Structure Name = OSNSat
Space Structure Type = Payload
Perigee Altitude = 402.000000 (km)
Apogee Altitude = 404.000000 (km)
Inclination = 51.643200 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.012857 (m^2/kg)
Start Year = 2016.000000 (yr)
Initial Mass = 0.630000 (kg)
Final Mass = 0.630000 (kg)
Duration = 1.000000 (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 ==========

05 11 2016; 01:38:10AM Requirement 4.5-2: Compliant
==========
Spacecraft = OSNSat
Critical Surface = New Critical Surface
==========
INPUT

Apogee Altitude = 404.000000 (km)
Perigee Altitude = 402.000000 (km)
Orbital Inclination = 51.643200 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass = 0.012857 (m^2/kg)
Initial Mass = 0.630000 (kg)
Final Mass = 0.630000 (kg)
Station Kept = No
Start Year = 2016.000000 (yr)
Duration = 1.000000 (yr)
Orientation = Random Tumbling
CS Areal Density = 7.777800 (g/cm^2)
CS Surface Area = 0.009900 (m^2)
Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
CS Pressurized = No

OUTPUT

Probabilty of Penitration = 0.000000
Returned Error Message: Normal Processing

Date Range Error Message: Normal Date Range

05 11 2016; 01:38:11AM Processing Requirement 4.6 Return Status :Passed
==========
Project Data
==========
INPUT

Space Structure Name = OSNSat
Space Structure Type = Payload

Perigee Altitude = 402.000000 (km)
Apogee Altitude = 404.000000 (km)
Inclination = 51.643200 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.012857 (m^2/kg)
Start Year = 2016.000000 (yr)
Initial Mass = 0.630000 (kg)
Final Mass = 0.630000 (kg)
Duration = 1.000000 (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 = 402.000000 (km)
Suggested Apogee Altitude = 404.000000 (km)
Returned Error Message = Reentry during mission (no PMD req.).

Released Year = 2016 (yr) Requirement = 61 Compliance Status = Pass

==========

========== End of Requirement 4.6 ==========

05 11 2016; 01:38:17AM *********Processing Requirement 4.7-1 Return Status : Passed

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

name = OSNSat
quantity = 1
parent = 0
materialID = 8
type = Cylinder
Aero Mass = 0.630000
Thermal Mass = 0.630000
Diameter/Width = 0.090000

name = OSNSat
quantity = 1
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 0.630000
Thermal Mass = 0.630000
Diameter/Width = 0.090000

Length = 0.130000

**********OUTPUT****
Item Number = 1
name = OSNSat
Demise Altitude = 77.994582
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = OSNSat
Demise Altitude = 69.108472
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

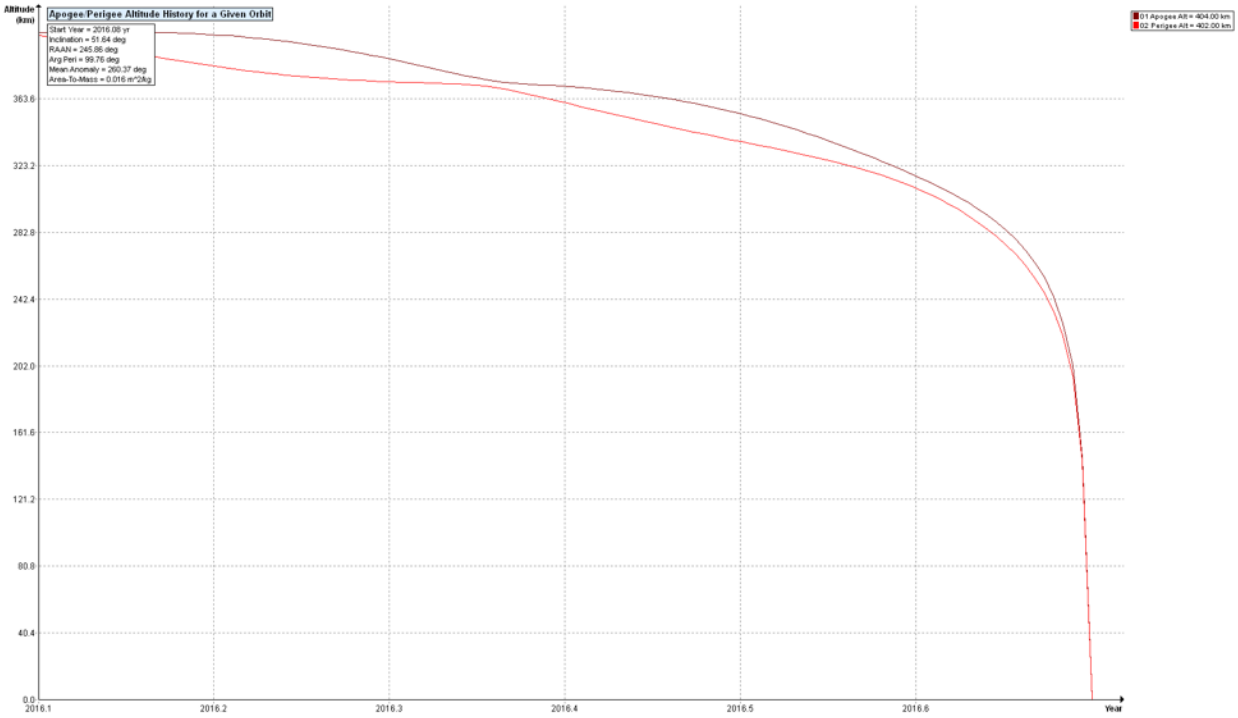
****
========== End of Requirement 4.7-1 ==========

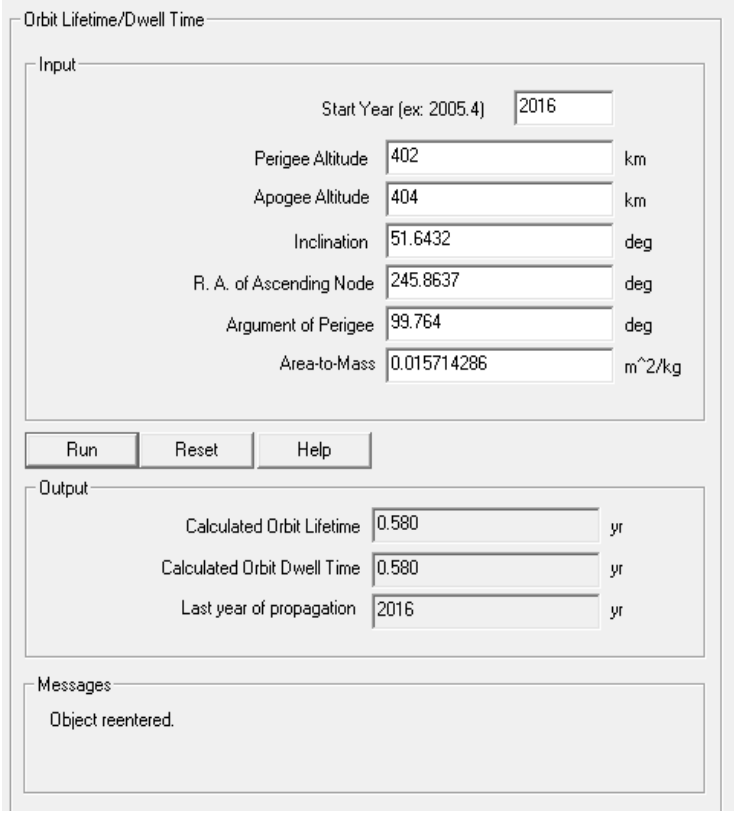
05 11 2016; 01:38:31AM Processing Requirement 4.8-1: Return Status :Passed
==========
Project Data
==========
INPUT
Tether Diameter = 1889785610
Tether Length = 0.130000
Tether Mass = 0.630000
EM Tether = No
Launch Year = 2016.000000
Deployed Year = 2016.080000
Retraction Year = 3000.000000
Perigee of Highest Mass = 402.000000
Apogee of Highest Mass = 404.000000
RAAN = 245.863700
Inclination = 51.643200
Argument of Perigee = 99.764000
Mass of Highest Altitude End Mass = 0.630000
Mass of Lowest Altitude End Mass = 0.630000
Cross Sectional Area of Highest Altitude End Mass = 0.010000

OUTPUT
sever = 0.000000

Plots

Apogee/Perigee Altitude History for a Given Orbit





Requirement 4.6-2. Disposal for space structures near GEO.

Analysis: Not applicable.

Requirement 4.6-3. Disposal for space structures between LEO and GEO.

Analysis: Not applicable.

Requirement 4.6-4. Reliability of Postmission Disposal Operations

Analysis: OSNSat-1 will reenter passively less than .7 year after launch and be entirely consumed during entry.

ODAR Section 7: Assessment of Spacecraft Reentry Hazards

A detailed description of spacecraft components includes 9 V lithium batteries; a thin carbon based 3D printed framework; circuitry. All components will vaporize. Assessment of spacecraft compliance with Requirement 4.7-1:

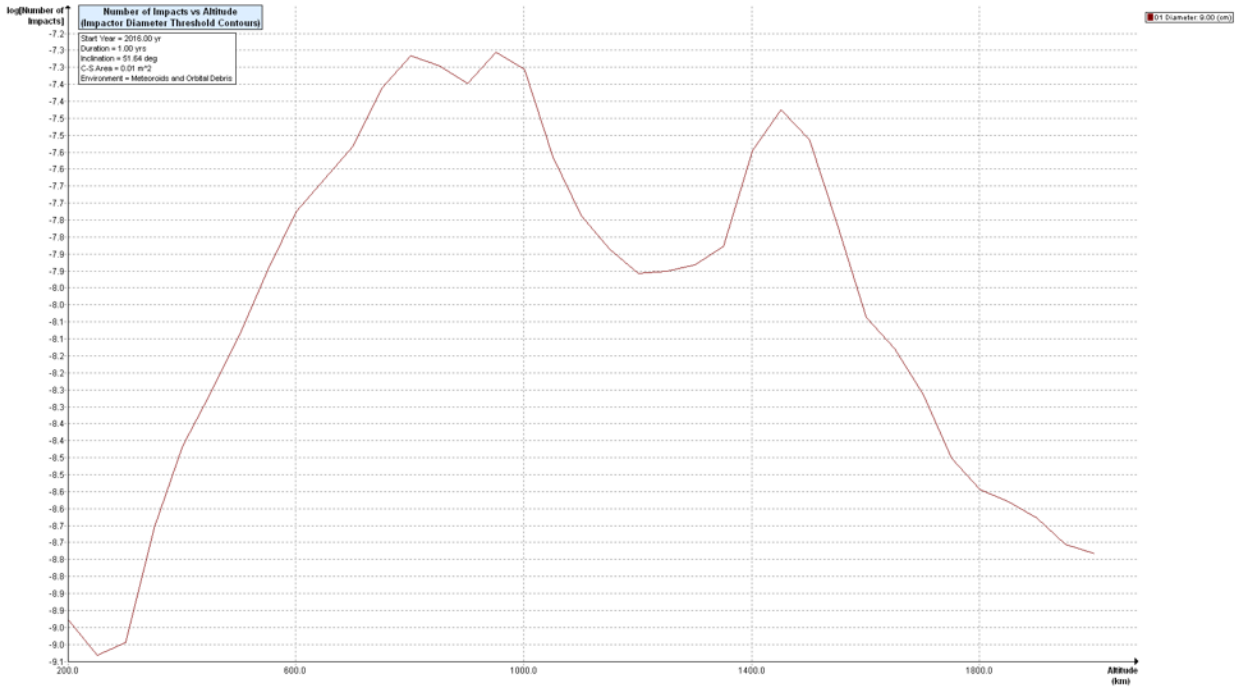
Requirement 4.7-1. Limit the risk of human casualty: The potential for human casualty is assumed for any object with an impacting kinetic energy in excess of 15 joules:

a. For uncontrolled reentry, the risk of human casualty from surviving debris shall not exceed 0.0001 (1:10,000) (Requirement 56626).

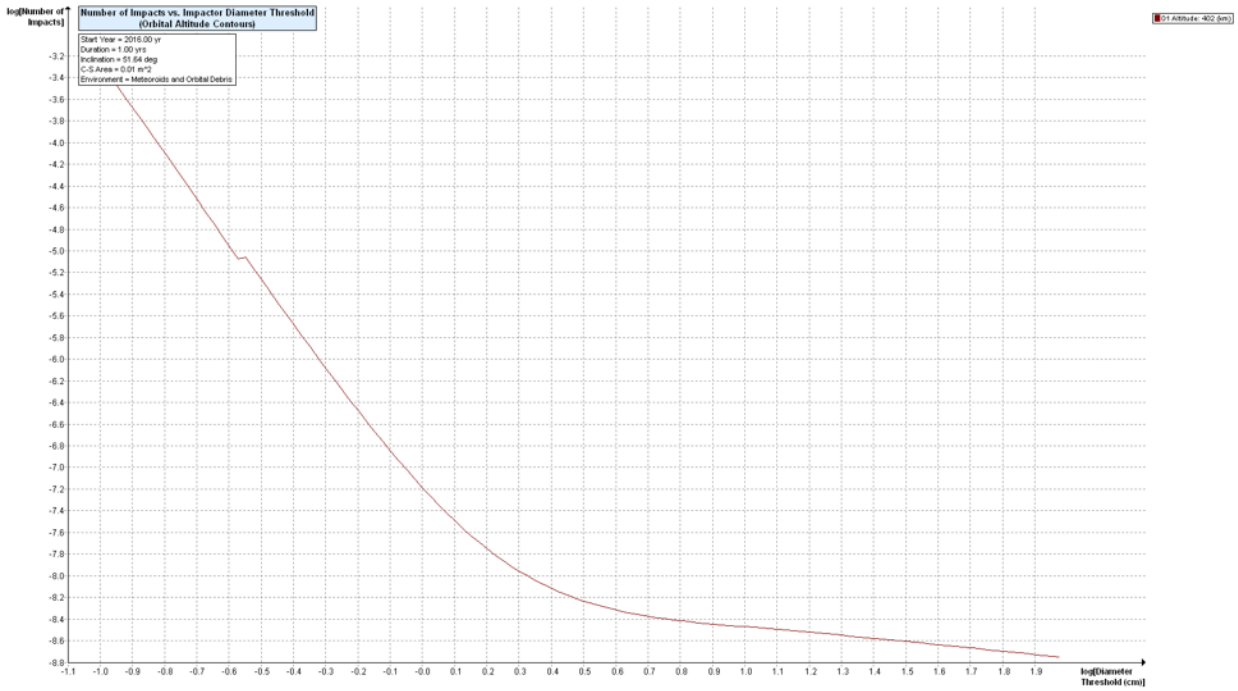
Summary Analysis Results: DAS v2.0.2 reports that OSNSat-1 is COMPLIANT with the requirement. No components are predicted by NASA DAS software to survive re-entry. The probability of human casualty due to uncontrolled reentry is 0.000000.

Analysis (per DAS v2.0.2):

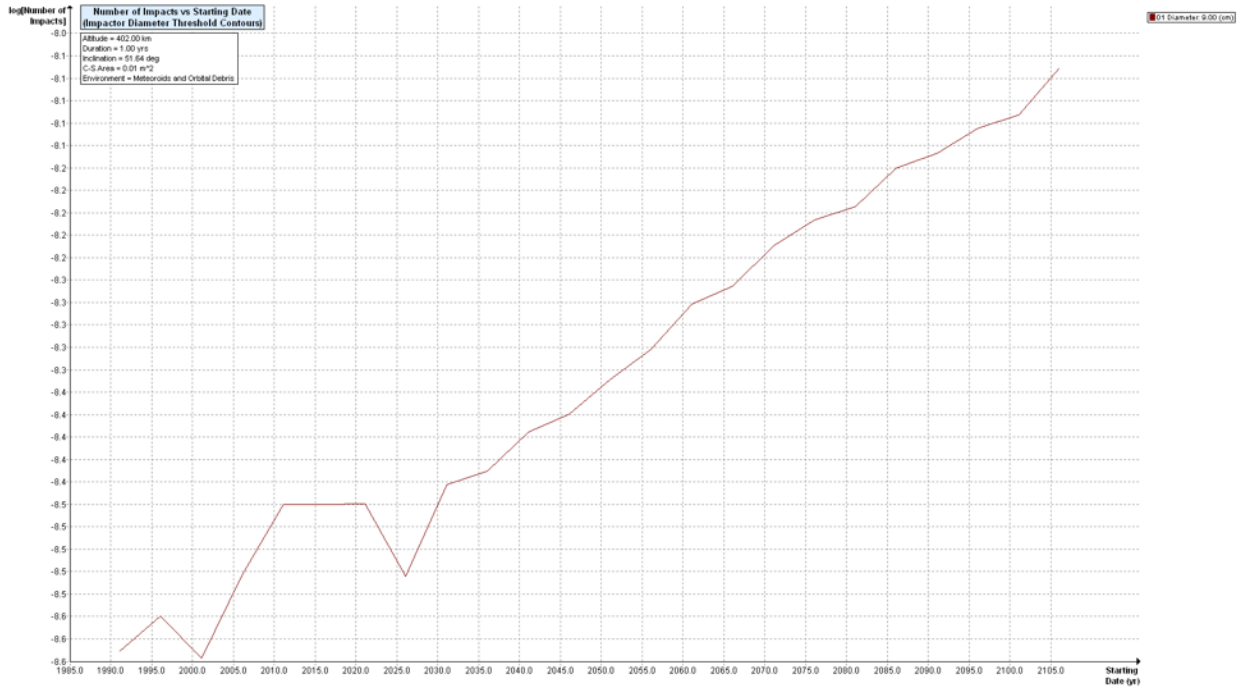
Debris Impact vs. Orbit Altitude



Debris Impact vs. Debris Diameter



Debris Impact vs. Date



4.7-1, b) **NOT APPLICABLE.** For controlled reentry, the selected trajectory shall ensure that no surviving debris impact with a kinetic energy greater than 15 joules is closer than 370 km from foreign landmasses, or is within 50 km from the continental U.S., territories of the U.S., and the permanent ice pack of Antarctica (Requirement 56627).

4.7-1 c) **NOT APPLICABLE.** For controlled reentries, the product of the probability of failure of the reentry burn (from Requirement 4.6-4.b) and the risk of human casualty assuming uncontrolled reentry shall not exceed 0.0001 (1:10,000) (Requirement 56628).

ODAR Section 7A: Assessment of Spacecraft Hazardous Materials

Not Applicable. There are no hazardous materials contained on the spacecraft.

ODAR Section 8: Assessment for Tether Missions

No tether will be used; this section is not applicable.