Orbital Debris Assessment Report

HF Varisat-2

per NASA-STD 8719.14A

Signature Page

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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 , Barba ra, 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 HF Varisat-2 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	April 2021

The following table summarizes the compliance status of the HF Varisat-2 spacecraft. The status 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 HF VariSat-2 mission, operated by VariSat LLC, is to experiment and gain flight heritage with a satellite designed to support HF marine data communications. A constellation of six satellites will be launched, to test the inter satellite link aspect of the system that is envisioned, as well as test ship to satellite and satellite to surface stations.

Also, experimental measurements will be made of on orbit spectral power density vs. frequency, in the 156 MHz and 900 MHz ranges, to help characterize channel congestion and noise floor in these ranges. This will help understand the suitability of these ranges for back up command and control, for future satellites.

The satellites, VariSat-2A, -2B, -2C, -2D, -2E and -2F, in deployers, will be transported to the ISS on NG-16 Cygnus from Wallops Island, Va, NET July 28, 2021, or SpaceX 23 from Cape Canaveral, Fl, NET August 15, 2021. The satellites in deployers will be mounted on the exterior of the NG-16 Cygnus vehicle while it is docked at the ISS, and after the Cygnus departs the ISS NET October 30 2021, they will be deployed from the Cygnus mounted deployers, into a circular orbit at 475 km, on an inclination from the equator of 51.6 degrees.

Transmission will begin 30 minutes after deploy from the Cygnus, and cease 2 years later. Atmospheric friction will slow the satellite and reduce the altitude of the orbit, until de-orbiting occurs. Per the DAS analysis discussed later in this report, that is estimated to be approximately 10 years after launch.

HF Varisat-2 Deployment CONOPS TBD Jeff please verify	
Timing	**Event**
Deploy of HF Varisat-2	Deployment Switch engage the Power up sequence
30 min	EPS Power Up
1 minute later	Cut burn wires to deploy Solar Arrays
Wait 90 minutes	Cut burn wire to antennas
1 minute later	Send Initial Transmission Beacon
1 minute later	Payload Power Up
1 minute later	Payload Nominal Operations

Schedule 1 Varisat-2 Deployment Schedule and CONOPS

Section 2: Spacecraft Description

Each of the six spacecraft is an identical unit with the dimensions of 6 stacked 10 cm X 10 cm X 10 cm CubeSat modules (giving an overall stowed dimension of 12 cm X 25.4 cm X 36.6 cm.) The total mass of each satellite is about 11 Kg.

Figure 1 shows the design for each of the six identical spacecraft.

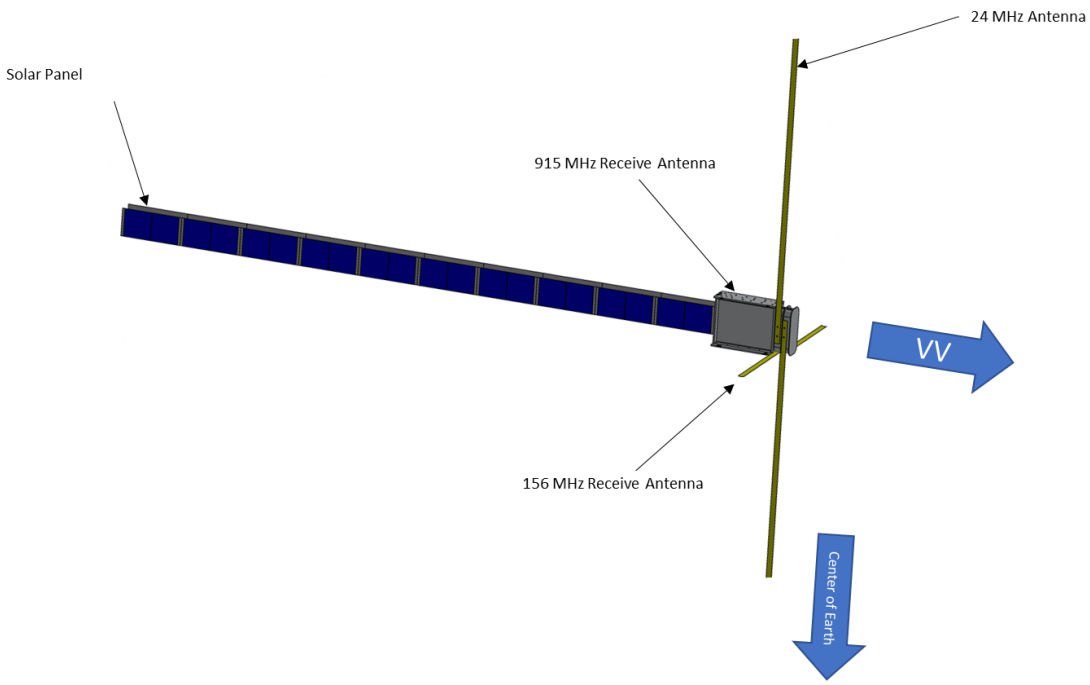

Figure 1 HF Varisat-2 Design, Typical for Each of Six Spacecraft

The Appendix lists all of the components in each spacecraft, with the characteristics of each.

Hazards

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

Batteries

The battery is a 72W-Hr NiMH battery, consisting of three individual NiMH battery packs. Each 12V/2000mA-Hr battery pack is comprised of 10 size AA cells. The packs are physically and thermally isolated from each other.

The NiMH battery is utilizes a circuit protection module providing over-charge/over-current and over-discharge protection. The satellite EPS also provides additional battery monitoring and protection functions.

Testing of the battery has 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.”

The technical requirements in the document provided a foundation for the NIMH test plan. There are differences between the batteries chemistry for LiOH and NiMH. The major difference is NiMH does not have thermal runaway characteristics that LiOH does. So referencing the LiOH test plan standards is seen to be conservative for NIMH.

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 small mass of the satellites and their short orbital lifetimes 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 "CubeSats as a satellite class need not disconnect their batteries if flown in LEO with orbital lifetimes less than 25 years."

Passivation of the batteries at end of mission is provided for in the command structure. However, the low amount of energy stored and small battery cells prevents a catastrophic failure; so that passivation at EOM is not necessary to prevent an explosion or deflagration large enough to release orbital debris. Also, the orbit lifetime worst case is estimated to be no more than 13.322 years.

Assessment of spacecraft compliance with Requirements 4.4-1 through 4.4-4 shows that the HF Varisat-2s are 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.

This analysis considers both the nominal case where all of the spacecraft deploy and the solar panels and antennas deploy, and aerodynamic forces orient the spacecraft in the ram direction as planned, and the contingent cases where the solar panels and antennas do not deploy, and/or they tumble instead of orienting.

Case 1: Deployed with Aerodynamic Stabilization (Nominal)

Per NASA STD-8719.14, ".. an object may be considered to be tumbling randomly, or it may be assumed to have a stable attitude relative to the velocity vector." At the altitude deployed, atmospheric drag is expected to stabilize attitude with the Z axis in the ram direction. The area presented to the RAM direction is calculated to be 0.0342 m^2.

With mass of 10.995 kg, the area to mass ratio in the stabilized attitude is 0.00311 m^2/kg.

From DAS, the orbit lifetime will be approximately 10.064 years and probability of collision with space objects larger than 10 cm in diameter during the orbital lifetime of the spacecraft, is 2.5971e-07.

Case 2: Deployed and Tumbling

A deployed, tumbling Varisat-2 can be regarded as a complex object. The formula for the MCSA of a complex object, tumbling, is given by NASA STD-8719.14.

$MCSA = (A_{max} + A_1 + A_2)/2$, where

A_{max} is the area of the orthogonal view with the greatest area

A_1 and A_2 are the areas of the other two orthogonal views.

From this formula, the deployed MCSA is calculated to be 0.302 m^2. The Area to mass ratio is therefore 0.0275 m^2/kg. From DAS, the orbit lifetime is approximately 1.84 year, and the probability of collision with space objects larger than 10 *cm* in diameter during the orbital lifetime of the spacecraft, is 7.7846e-07.

Case 3: Un-Deployed With Aerodynamic Stabilization

The longest orbit lifetime would result if the solar panels and antenna did not deploy, and if the satellite stabilized with the minimum area face in the RAM direction. This yields an MCSA of 0.0238 m^2, and an area to mass ratio of 0.0022 m^2/kg . From DAS, the orbit lifetime is approximately 13.322 years, and the probability of collision with space objects larger than 10 *cm* in diameter during the orbital lifetime of the spacecraft, is 2.8175e-07.

Case 4: Un-Deployed with Tumbling

As a contingency we consider the unexpected case where all of the spacecraft, when ejected from the launcher tube, remained undeployed, e.g., do not unfold, and tumble. The formula for the MCSA of a complex object, tumbling, is given by NASA STD-8719.14.

MCSA = Surface Area / 4 (which for rectangular solids reduces to the formula used in Case 2 also).

This yields an MCSA area of 0.0738 m^2, and an area to mass ratio of 0.0067 m^2/kg. From DAS, the orbit lifetime is approximately 4.222 years, and the probability of collision with space objects larger than 10 *cm* in diameter during the orbital lifetime of the spacecraft, is 3.2657e-07.

Review of All Cases

In summary, the probability of any collision, in any configuration, with debris or meteoroids greater than 10 cm in diameter is 7.7846e-07, per DAS, worst case (deployed and tumbling). This satisfies the 0.001 maximum probability requirement 4.5-l.

The spacecraft have 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 the spacecraft to be compliant. Requirement 4.5-2 is not applicable to this mission.

Section 6: Assessment of Spacecraft Post Mission Disposal Plans and Procedures

The spacecraft in all cases will naturally decay from orbit within 25 years after launch, 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 3.1.2 version Orbital Lifetime Calculations:

DAS inputs are: 475 km apogee and 475 km perigee, on an inclination from the equator of 51.6 degrees, with deployment in 2021.

As an extreme outer limit for orbit lifetime is Case 3 above, the contingency mode wherein the solar panels and antennas does not unfold, and the satellite is assumed stable in flight, yields a value of 13.322 years. There is no mode in which the spacecraft would be estimated to stay in orbit longer than 13.322 years.

The assessment of the spacecraft illustrates they are 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 version 3.1.2, to verify Requirement 4.7-1. See Appendix for a complete log of DAS inputs and outputs for all cases. 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 of 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
156 MHz Antenna	**0.049**	**3.21**	**1.01**	**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 terminal energy of the only surviving component 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 HF Varisat-2 satellites thus are 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.

DAS Activity Log

```
04 22 2021; 15:25:26PM Activity Log Started
04 22 2021; 15:25:26PM Project Files copied from C:\Users\mille\Sterk\VERISAT DAS\
04 22 2021; 15:25:26PM Project Data Saved To File
04 22 2021; 15:26:02PM Mission Editor Changes Applied
04 22 2021; 15:26:02PM Project Data Saved To File
04 22 2021; 15:26:16PM Mission Editor Changes Applied
04 22 2021; 15:26:16PM Project Data Saved To File
04 22 2021; 15:35:57PM Processing Requirement 4.5-1:     Return Status :  Passed
==============
Run Data
==============
**INPUT**
      Space Structure Name = Varisat-2
      Space Structure Type = Payload
      Perigee Altitude = 475.000 (km)
      Apogee Altitude = 475.000 (km)
      Inclination = 51.600 (deg)
      RAAN = 0.000 (deg)
      Argument of Perigee = 0.000 (deg)
      Mean Anomaly = 0.000 (deg)
      Final Area-To-Mass Ratio = 0.0031 (m^2/kg)
      Start Year = 2021.000 (yr)
      Initial Mass = 10.995 (kg)
      Final Mass = 10.995 (kg)
      Duration = 10.000 (yr)
      Station-Kept = False
      Abandoned = True
**OUTPUT**
      Collision Probability = 2.5971E-07
      Returned Message: Normal Processing
      Date Range Message: Normal Date Range
      Status = Pass
==============
=============== End of Requirement 4.5-1 ===============
04 22 2021; 15:36:16PM Project Data Saved To File
04 22 2021; 15:36:21PM Requirement 4.5-2:  Compliant
=============== End of Requirement 4.5-2 ===============
04 22 2021; 15:37:36PM Science and Engineering - Orbit Lifetime/Dwell Time
**INPUT**
      Start Year = 2021.750000 (yr)
      Perigee Altitude = 475.000000 (km)
      Apogee Altitude = 475.000000 (km)
      Inclination = 51.600000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Area-To-Mass Ratio = 0.003110 (m^2/kg)
**OUTPUT**
      Orbital Lifetime from Startyr = 10.064339 (yr)
      Time Spent in LEO during Lifetime  = 10.064339 (yr)
      Last year of Propagation = 2031 (yr)
      Returned Error Message: Object reentered
04 22 2021; 15:38:28PM Mission Editor Changes Applied
04 22 2021; 15:38:28PM Project Data Saved To File
04 22 2021; 15:41:14PM Processing Requirement 4.5-1:     Return Status :  Passed
==============
Run Data
==============
```

```
**INPUT**
      Space Structure Name = Varisat-2
      Space Structure Type = Payload
      Perigee Altitude = 475.000 (km)
      Apogee Altitude = 475.000 (km)
      Inclination = 51.600 (deg)
      RAAN = 0.000 (deg)
      Argument of Perigee = 0.000 (deg)
      Mean Anomaly = 0.000 (deg)
      Final Area-To-Mass Ratio = 0.0275 (m^2/kg)
      Start Year = 2021.000 (yr)
      Initial Mass = 10.995 (kg)
      Final Mass = 10.995 (kg)
      Duration = 10.000 (yr)
      Station-Kept = False
      Abandoned = True
**OUTPUT**
      Collision Probability = 7.7846E-07
      Returned Message: Normal Processing
      Date Range Message: Normal Date Range
      Status = Pass
==============
=============== End of Requirement 4.5-1 ===============
04 22 2021; 15:41:32PM Project Data Saved To File
04 22 2021; 15:41:39PM Requirement 4.5-2:  Compliant
=============== End of Requirement 4.5-2 ===============
04 22 2021; 15:41:56PM Science and Engineering - Orbit Lifetime/Dwell Time
**INPUT**
      Start Year = 2021.750000 (yr)
      Perigee Altitude = 475.000000 (km)
      Apogee Altitude = 475.000000 (km)
      Inclination = 51.600000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Area-To-Mass Ratio = 0.027500 (m^2/kg)
**OUTPUT**
      Orbital Lifetime from Startyr = 1.839836 (yr)
      Time Spent in LEO during Lifetime  = 1.839836 (yr)
      Last year of Propagation = 2023 (yr)
      Returned Error Message: Object reentered
04 22 2021; 15:42:44PM Mission Editor Changes Applied
04 22 2021; 15:42:44PM Project Data Saved To File
04 22 2021; 15:55:43PM Processing Requirement 4.5-1:     Return Status :  Passed
==============
Run Data
==============
**INPUT**
      Space Structure Name = Varisat-2
      Space Structure Type = Payload
      Perigee Altitude = 475.000 (km)
      Apogee Altitude = 475.000 (km)
      Inclination = 51.600 (deg)
      RAAN = 0.000 (deg)
      Argument of Perigee = 0.000 (deg)
      Mean Anomaly = 0.000 (deg)
      Final Area-To-Mass Ratio = 0.0022 (m^2/kg)
      Start Year = 2021.000 (yr)
      Initial Mass = 10.995 (kg)
      Final Mass = 10.995 (kg)
      Duration = 10.000 (yr)
```

```
      Station-Kept = False
      Abandoned = True
**OUTPUT**
      Collision Probability = 2.8175E-07
      Returned Message: Normal Processing
      Date Range Message: Normal Date Range
      Status = Pass
==============
=============== End of Requirement 4.5-1 ===============
04 22 2021; 15:56:06PM Project Data Saved To File
04 22 2021; 15:56:10PM Requirement 4.5-2:  Compliant
=============== End of Requirement 4.5-2 ===============
04 22 2021; 15:56:20PM Science and Engineering - Orbit Lifetime/Dwell Time
**INPUT**
      Start Year = 2021.750000 (yr)
      Perigee Altitude = 475.000000 (km)
      Apogee Altitude = 475.000000 (km)
      Inclination = 51.600000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Area-To-Mass Ratio = 0.002200 (m^2/kg)
**OUTPUT**
      Orbital Lifetime from Startyr = 13.322382 (yr)
      Time Spent in LEO during Lifetime  = 13.322382 (yr)
      Last year of Propagation = 2035 (yr)
      Returned Error Message: Object reentered
04 22 2021; 15:56:40PM Mission Editor Changes Applied
04 22 2021; 15:56:40PM Project Data Saved To File
04 22 2021; 16:01:29PM Processing Requirement 4.5-1:     Return Status :  Passed
==============
Run Data
==============
**INPUT**
      Space Structure Name = Varisat-2
      Space Structure Type = Payload
      Perigee Altitude = 475.000 (km)
      Apogee Altitude = 475.000 (km)
      Inclination = 51.600 (deg)
      RAAN = 0.000 (deg)
      Argument of Perigee = 0.000 (deg)
      Mean Anomaly = 0.000 (deg)
      Final Area-To-Mass Ratio = 0.0067 (m^2/kg)
      Start Year = 2021.000 (yr)
      Initial Mass = 10.995 (kg)
      Final Mass = 10.995 (kg)
      Duration = 10.000 (yr)
      Station-Kept = False
      Abandoned = True
**OUTPUT**
      Collision Probability = 3.2657E-07
      Returned Message: Normal Processing
      Date Range Message: Normal Date Range
      Status = Pass
==============
=============== End of Requirement 4.5-1 ===============
04 22 2021; 16:01:52PM Project Data Saved To File
04 22 2021; 16:01:58PM Requirement 4.5-2:  Compliant
=============== End of Requirement 4.5-2 ===============
04 22 2021; 16:02:09PM Science and Engineering - Orbit Lifetime/Dwell Time
**INPUT**
```

```
      Start Year = 2021.750000 (yr)
      Perigee Altitude = 475.000000 (km)
      Apogee Altitude = 475.000000 (km)
      Inclination = 51.600000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Area-To-Mass Ratio = 0.006700 (m^2/kg)
**OUTPUT**
      Orbital Lifetime from Startyr = 4.221766 (yr)
      Time Spent in LEO during Lifetime  = 4.221766 (yr)
      Last year of Propagation = 2025 (yr)
      Returned Error Message: Object reentered

04 22 2021; 16:08:36PM Project Data Saved To File
04 22 2021; 16:08:49PM Processing Requirement 4.6   Return Status :  Passed
==============
Project Data
==============
**INPUT**
      Space Structure Name = Varisat-2
      Space Structure Type = Payload
      Perigee Altitude = 475.000000 (km)
      Apogee Altitude = 475.000000 (km)
      Inclination = 51.600000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Area-To-Mass Ratio = 0.006700 (m^2/kg)
      Start Year = 2021.000000 (yr)
      Initial Mass = 10.995000 (kg)
      Final Mass = 10.995000 (kg)
      Duration = 10.000000 (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 = 475.000000 (km)
      Suggested Apogee Altitude = 475.000000 (km)
      Returned Error Message = Reentry during mission (no PMD req.).
      Released Year = 2025 (yr)
      Requirement = 61
      Compliance Status = Pass
==============
=============== End of Requirement 4.6 ===============
04 22 2021; 16:08:49PM *********Processing Requirement 4.7-1
      Return Status :  Passed
***********INPUT****
 Item Number = 1
name = Varisat-2
quantity = 1
parent = 0
materialID = 8
type = Box
Aero Mass = 10.995000
Thermal Mass = 10.995000
```

```
Diameter/Width = 0.254000
Length = 0.366000
Height = 0.120000
name = Solar Array Panel
quantity = 16
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.147500
Thermal Mass = 0.147500
Diameter/Width = 0.200000
Length = 0.266000
name = Small Drag Panel/915 MHZ Antenna
quantity = 2
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.216000
Thermal Mass = 0.216000
Diameter/Width = 0.080000
Length = 0.366000
name = Large Side Panels
quantity = 4
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.231000
Thermal Mass = 0.231000
Diameter/Width = 0.153000
Length = 0.206000
name = Narrow Side Panels
quantity = 4
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.090000
Thermal Mass = 0.090000
Diameter/Width = 0.080000
Length = 0.153000
name = Body Tubes
quantity = 8
parent = 1
materialID = 8
type = Box
Aero Mass = 0.060000
Thermal Mass = 0.060000
Diameter/Width = 0.025400
Length = 0.146000
Height = 0.025400
name = Centerbody
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.546000
Thermal Mass = 0.546000
Diameter/Width = 0.100000
Length = 0.226000
Height = 0.092000
name = End Plate Radiators
```

```
quantity = 2
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.249000
Thermal Mass = 0.249000
Diameter/Width = 0.100000
Length = 0.226000
name = Battery Pack
quantity = 3
parent = 1
materialID = 54
type = Box
Aero Mass = 0.267000
Thermal Mass = 0.267000
Diameter/Width = 0.052000
Length = 0.071000
Height = 0.030000
name = 156 MHz Dipole Antenna
quantity = 2
parent = 1
materialID = 54
type = Flat Plate
Aero Mass = 0.049000
Thermal Mass = 0.049000
Diameter/Width = 0.025400
Length = 0.480000
name = Lime SDR Board
quantity = 2
parent = 1
materialID = 54
type = Box
Aero Mass = 0.375000
Thermal Mass = 0.375000
Diameter/Width = 0.059000
Length = 0.088000
Height = 0.017000
name = Raspberry PI 4 Computer
quantity = 2
parent = 1
materialID = 54
type = Box
Aero Mass = 0.375000
Thermal Mass = 0.375000
Diameter/Width = 0.059000
Length = 0.088000
Height = 0.017000
name = Linear Amp
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.061000
Thermal Mass = 0.061000
Diameter/Width = 0.035000
Length = 0.035000
Height = 0.020000
name = RF Board
quantity = 1
parent = 1
```

```
materialID = 54
type = Box
Aero Mass = 0.375000
Thermal Mass = 0.375000
Diameter/Width = 0.059000
Length = 0.088000
Height = 0.017000
name = Power Board
quantity = 1
parent = 1
materialID = 54
type = Box
Aero Mass = 0.500000
Thermal Mass = 0.500000
Diameter/Width = 0.059000
Length = 0.088000
Height = 0.017000
name = LoRa Radio
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.200000
Thermal Mass = 0.200000
Diameter/Width = 0.059000
Length = 0.088000
Height = 0.017000
name = GPS Board
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.059000
Length = 0.088000
Height = 0.017000
name = GPS Antenna
quantity = 2
parent = 1
materialID = 54
type = Cylinder
Aero Mass = 0.200000
Thermal Mass = 0.200000
Diameter/Width = 0.030000
Length = 0.035000
name = Fasteners
quantity = 80
parent = 1
materialID = 54
type = Cylinder
Aero Mass = 0.015000
Thermal Mass = 0.015000
Diameter/Width = 0.030000
Length = 0.019000
name = Antenna (Nitinol)
quantity = 1
parent = 1
materialID = 46
type = Cylinder
```

```
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.002000
Length = 6.080000
name = Antenna (copper)
quantity = 1
parent = 1
materialID = 19
type = Cylinder
Aero Mass = 0.061000
Thermal Mass = 0.061000
Diameter/Width = 0.001200
Length = 6.080000
**************OUTPUT****
Item Number = 1
name = Varisat-2
Demise Altitude = 77.998215
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = Solar Array Panel
Demise Altitude = 77.345253
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = Small Drag Panel/915 MHZ Antenna
Demise Altitude = 76.562248
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = Large Side Panels
Demise Altitude = 76.541443
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = Narrow Side Panels
Demise Altitude = 76.913071
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = Body Tubes
Demise Altitude = 76.681641
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = Centerbody
Demise Altitude = 75.240990
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = End Plate Radiators
Demise Altitude = 75.259399
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = Battery Pack
Demise Altitude = 61.038620
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
```

```
name = 156 MHz Dipole Antenna
Demise Altitude = 0.000000
Debris Casualty Area = 1.009386
Impact Kinetic Energy = 3.213190
************************************
name = Lime SDR Board
Demise Altitude = 57.865780
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = Raspberry PI 4 Computer
Demise Altitude = 57.865780
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = Linear Amp
Demise Altitude = 73.885208
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = RF Board
Demise Altitude = 57.865780
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = Power Board
Demise Altitude = 57.686558
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = LoRa Radio
Demise Altitude = 73.078125
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = GPS Board
Demise Altitude = 75.416985
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = GPS Antenna
Demise Altitude = 62.328403
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = Fasteners
Demise Altitude = 74.369705
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = Antenna (Nitinol)
Demise Altitude = 77.288696
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
name = Antenna (copper)
Demise Altitude = 77.707756
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
************************************
```

```
=============== End of Requirement 4.7-1 ===============
04 22 2021; 16:08:49PM Project Data Saved To File
```