Orbital Debris Assessment Report

Produced by Care Weather Technologies for the Veery-RL1 Mission

In Accordance with NASA-STD 8719.14A

Revision History and Signatures

Revision	Notes	Produced By	Checked By	Date
A	First Version	 Patrick Walton CEO, Care Weather Veery Mission Manager	 Alex Laraway CTO, Care Weather Veery System Engineer	12/06/2020

Summary of Compliance

Sections 1 through 8 of Process for Limiting Orbital Debris, NASA-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.

The following table summarizes the compliance status of the Veery-RL1 spacecraft. It is fully compliant with all applicable requirements.

Table 1. Compliance Assessment Per Requirement

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	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	

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 Veery-RL1 mission.

Section 1: Mission Overview

The primary objective of the Veery-RL1 Mission is to test the performance of Care Weather's nanosatellite bus technologies, including power, computing, communications, structures, and avionics. Instrumentation on board the satellite will measure the performance of these systems. System data will be relayed to the ground over the Iridium satellite network using an Iridium 9603 satellite modem. Veery-RL1 is a pathfinder for the future Veery scatterometer constellation, which will fill critical gaps in U.S. scatterometer ocean vector wind weather data. Veery data will provide unprecedented insight into tropical convection, enable next-generation forecasts, accelerate early warnings for our nation's most costly disasters.

Section 2: Spacecraft Description

Veery RL1 uses a 1U Cubesat form factor with rails, measuring 100 mm x 100 mm x 113.5 mm. This provides a cross-sectional area greater than 0.01 m^2.

Hazards

Veery RL1 has no pressure vessels, hazardous materials, or exotic materials.

Batteries

Veery RL1 uses Lithium batteries managed by protective control circuitry. The battery control circuitry has an extensive suite of protections that have been demonstrated through hundreds of hours of ground testing in hot and cool environments. Each battery has at least two methods of protection against each possible method failure. These protections include:

1. Protection from over-charge voltage: The battery charge controller for each battery has a maximum output voltage setting. When a battery reaches this float voltage, the charger directs current to the satellite system, bypassing the batteries and preventing overcharging. The microcontroller also continuously monitors charge current and can disable charging if an error condition is met.
2. Protection from over-charge current: The battery charge controller for each battery has a maximum charge current setting which is set to half the maximum charge current for each battery. The microcontroller also supervises this current and can disable charging from individual batteries as needed.
3. Protection from over-discharge current or short circuits: The high-side enable switch limits current draw to within the current capacity of each battery. In addition to this, a

low side protection circuit disables a battery instantly if an extreme current draw is reached.

4. Protection from under-voltage: The low side circuit protection disables batteries when voltage drops too near to the minimum battery voltage. Hysteresis is implemented to not release this error state until the battery reaches a voltage state that is higher than the shutoff voltage. In addition to this, the microcontroller puts the system to sleep during this time, enabling the batteries to charge without load.

5. Protection from over-temperature: A temperature sensing circuit internal to the battery charge controller disables charging at above a temperature that is near but below the maximum allowable operating temperature of the batteries. In order to prevent discharge during this time, an analog timing circuit powers the entire system off, periodically waking briefly to check whether the temperature has dropped again to acceptable operating levels.

6. Protection from under-temperature: The microcontroller enables resistance heaters when the battery temperature drops near or below the minimum battery operating temperature. These heaters are powered until the batteries reach a temperature that is much higher than the shutoff temperature, at which time they are powered off.

Section 3: Assessment of Spacecraft Debris Released During Normal Operations
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 the effect of an explosion on the far-term LEO environment is negligible, per NASA 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) in accordance with NASA HQ OSMA policy which states that "CubeSats [3U or smaller] 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 that the satellite is compliant.

Section 5: Assessment of Spacecraft Potential for On Orbit Collisions

NASA Debris Assessment software was used to evaluate the probability of collision with large objects. See Appendix A-B for the DAS activity log, which shows that the probability of an on orbit collision is 2.24E-07. This satisfies the 0.001 maximum probability requirement 4.5-l.

The spacecraft has no capability nor plans for end-of-mission disposal, therefore requirement 4.5-2 is not applicable.

Assessment of spacecraft compliance with Requirements 4.5-1 shows it to be compliant.
Requirement 4.5-2 is not applicable to this mission.

Section 6: Assessment of Spacecraft Post-mission Disposal Plans and Procedures

Planning for spacecraft maneuvers to accomplish post-mission disposal is not applicable. Disposal is achieved via passive atmospheric reentry. Veery's orbit will naturally decay due to atmospheric drag until it re-enters the atmosphere 3.7 years after it is released on orbit. This is well under the 25-year rule of requirement 4.6- l.

Summary of DAS 3.1.0 Orbital Lifetime Calculations

DAS inputs are: 550 km circular orbit, with an inclination of 45° at deployment no earlier than February 16, 2021. The lifetime of the spacecraft is estimated to be approximately 3.7 years until demise, as shown in Fig. 1.

This assessment of the spacecraft orbital life illustrates it is compliant with Requirements 4.6-1 through 4.6-5.

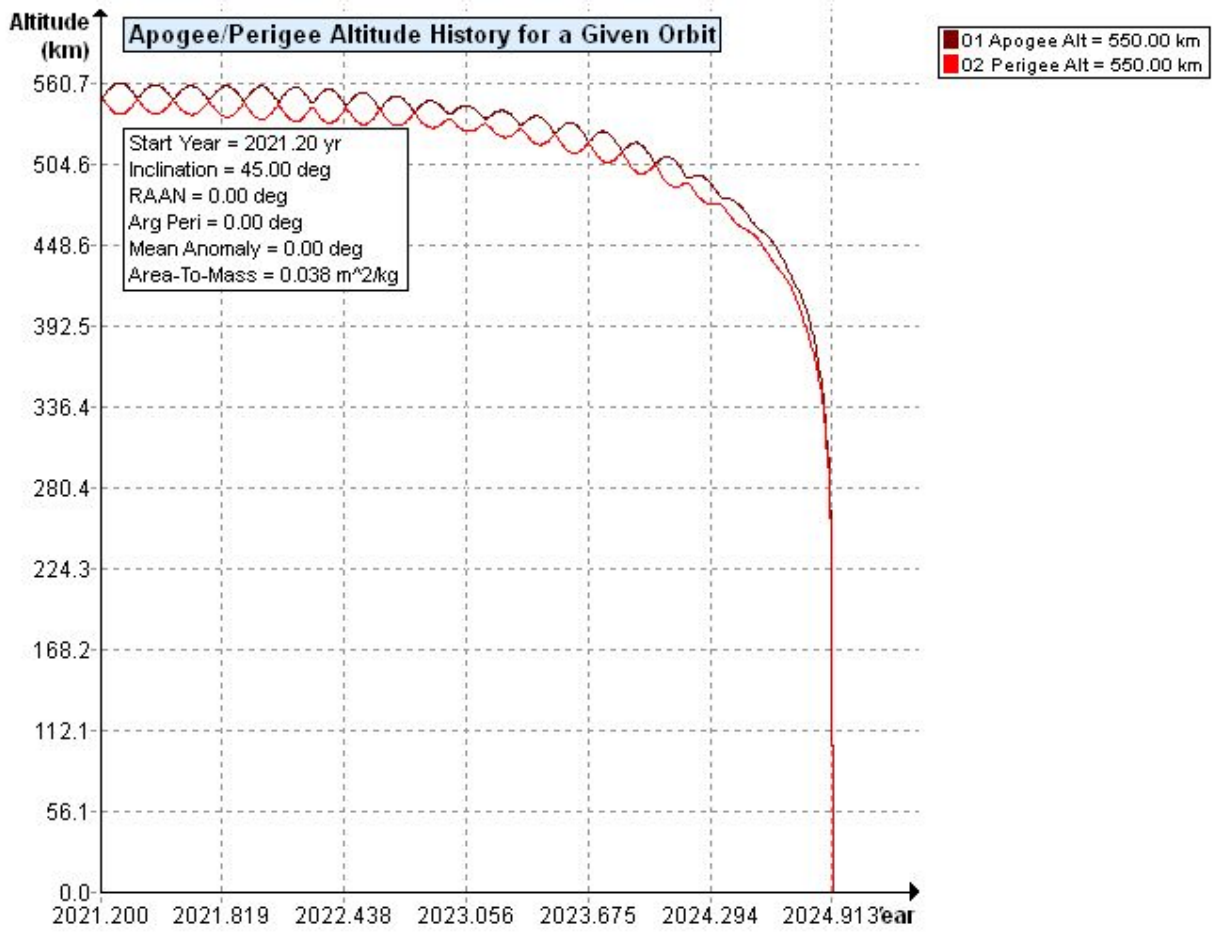

Figure 1. Altitude vs. Time For Veery-RL1 Spacecraft Starting at 550 km Orbit. Obtained Using NASA DAS 3.1.0. See Appendix B for More Details.

Section 7: Assessment of Spacecraft Re-entry Hazards

A detailed assessment of the components of the spacecraft was performed using DAS 3.1.0, to verify Requirement 4.7-1 for the 550 km orbit. See Appendix A-B, the DAS Activity Log, for more details. All components are demised above 76 km and the probability of human casualty is 1:100,000,000, thus Veery-RL1 complies with the less than 1:10,000 probability of Human Casualty Requirement 4.7-1.

The satellites are thus 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.

Sections 9-14:

ODAR sections 9-14 pertain to the launch vehicle and are not covered here.

References

A. NASA Procedural Requirements for Limiting Orbital Debris Generation, NPR 8715.6A, 5 February 2008

B. Process for Limiting Orbital Debris, NASA-STD-8719.14A, 25 May 2012

C. GSFC, NASA. General Environmental Verification Standard (GEVS) for GSFC Flight Programs and Projects. GSFC-STD-7000A), NASA Goddard Space Flight Center, Greenbelt, MD, USA, 2013.

D. HQ OSMA Policy Memo/Email to 8719.14: CubeSat Battery Non-Passivation, Suzanne Aleman to Justin Treptow, 10, March 2014

E. HQ OSMA Email:6U CubeSat Battery Non Passivation Suzanne Aleman to Justin Treptow, 8 August 2017

Appendix A: Requirements Analysis Activity Log From NASA Debris Assessment Software

(DAS 3.1.0)

```
12 06 2020; 18:09:53PM   Activity Log Started
12 06 2020; 18:11:53PM   Mission Editor Changes Applied
12 06 2020; 18:11:53PM   Project Data Saved To File
12 06 2020; 18:12:10PM   Processing Requirement 4.3-1: Return
Status :  Not Run

=====================
No Project Data Available
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=============== End of Requirement 4.3-1 ===============
12 06 2020; 18:12:12PM   Processing  Requirement  4.3-2:  Return
Status : Passed

=====================
No Project Data Available
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=============== End of Requirement 4.3-2 ===============
12 06 2020; 18:29:38PM   Processing Requirement 4.5-1: Return
Status :  Passed

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

**INPUT**

     Space Structure Name = 1U CubeSat 1
     Space Structure Type = Payload
     Perigee Altitude = 550.000 (km)
     Apogee Altitude = 550.000 (km)
     Inclination = 45.000 (deg)
```

RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0385 (m^2/kg)
Start Year = 2021.100 (yr)
Initial Mass = 1.330 (kg)
Final Mass = 1.330 (kg)
Duration = 0.500 (yr)
Station-Kept = False
Abandoned = True

OUTPUT

Collision Probability = 3.2538E-07
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

==========

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

12 06 2020; 18:29:42PM Project Data Saved To File
12 06 2020; 18:34:49PM Requirement 4.5-2: Compliant

==========
Spacecraft = 1U CubeSat 1
Critical Surface = Solar Panel
==========

INPUT

Apogee Altitude = 550.000 (km)
Perigee Altitude = 550.000 (km)
Orbital Inclination = 45.000 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass = 0.0385 (m^2/kg)

```
     Initial Mass = 1.330 (kg)
     Final Mass = 1.330 (kg)
     Station Kept = No
     Start Year = 2021.100 (yr)
     Duration = 0.500 (yr)
     Orientation = Random Tumbling
     CS Areal Density = 1.000 (g/cm^2)
     CS Surface Area = 0.0100 (m^2)
     Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
     CS Pressurized = No

**OUTPUT**

     Probability of Penetration = 2.1413E-03 (2.1436E-03)
     Returned Error Message: Normal Processing
     Date Range Error Message: Normal Date Range

=============== End of Requirement 4.5-2 ===============

12 06 2020; 18:47:40PM   Processing Requirement 4.6    Return
Status :  Passed

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

**INPUT**

     Space Structure Name = 1U CubeSat 1
     Space Structure Type = Payload

     Perigee Altitude = 550.000000 (km)
     Apogee Altitude = 550.000000 (km)
     Inclination = 45.000000 (deg)
     RAAN = 0.000000 (deg)
     Argument of Perigee = 0.000000 (deg)
     Mean Anomaly = 0.000000 (deg)
     Area-To-Mass Ratio = 0.038500 (m^2/kg)
     Start Year = 2021.100000 (yr)
```

```
     Initial Mass = 1.330000 (kg)
     Final Mass = 1.330000 (kg)
     Duration = 0.500000 (yr)
     Station Kept = False
     Abandoned = True
     PMD Perigee Altitude = 541.909345 (km)
     PMD Apogee Altitude = 554.748793 (km)
     PMD Inclination = 44.998884 (deg)
     PMD RAAN = 114.357589 (deg)
     PMD Argument of Perigee = 133.929470 (deg)
     PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

     Suggested Perigee Altitude = 541.909345 (km)
     Suggested Apogee Altitude = 554.748793 (km)
     Returned Error Message = Passes LEO reentry orbit criteria.

     Released Year = 2024 (yr)
     Requirement = 61
     Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
12 06 2020; 18:47:50PM   *********Processing Requirement 4.7-1
     Return Status :  Passed

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

name = 1U CubeSat 1
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 1.330000
Thermal Mass = 1.330000
Diameter/Width = 0.100000
```

```
Length = 0.100000
Height = 0.100000

name = New Component
quantity = 10
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.100000
Length = 0.100000

name = New Component1
quantity = 6
parent = 1
materialID = 8
type = Box
Aero Mass = 0.075000
Thermal Mass = 0.075000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.005000

name = New Component2
quantity = 4
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 0.020000
Thermal Mass = 0.020000
Diameter/Width = 0.010000
Length = 0.090000

name = New Component3
quantity = 10
parent = 1
materialID = 23
type = Flat Plate
```

```
Aero Mass = 0.008000
Thermal Mass = 0.008000
Diameter/Width = 0.050000
Length = 0.050000

name = New Component4
quantity = 30
parent = 1
materialID = 54
type = Cylinder
Aero Mass = 0.000100
Thermal Mass = 0.000100
Diameter/Width = 0.002000
Length = 0.005000

name = New Component5
quantity = 2
parent = 1
materialID = 54
type = Cylinder
Aero Mass = 0.000200
Thermal Mass = 0.000200
Diameter/Width = 0.002000
Length = 0.010000

name = New Component6
quantity = 4
parent = 1
materialID = 54
type = Cylinder
Aero Mass = 0.001000
Thermal Mass = 0.001000
Diameter/Width = 0.002000
Length = 0.050000

name = New Component7
quantity = 3
parent = 1
materialID = 19
```

```
type = Box
Aero Mass = 0.003000
Thermal Mass = 0.003000
Diameter/Width = 0.015000
Length = 0.015000
Height = 0.003000

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

name = 1U CubeSat 1
Demise Altitude = 77.998634
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = New Component
Demise Altitude = 77.014465
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = New Component1
Demise Altitude = 75.950485
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = New Component2
Demise Altitude = 76.215691
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = New Component3
Demise Altitude = 77.528725
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
************************************
name = New Component4
Demise Altitude = 77.214462
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = New Component5
Demise Altitude = 77.106430
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = New Component6
Demise Altitude = 76.987000
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = New Component7
Demise Altitude = 76.818901
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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

=============== End of Requirement 4.7-1 ===============
12 06 2020; 18:47:50PM   Project Data Saved To File
```

Appendix B: Orbital Life Analysis Activity Log From NASA Debris Assessment Software

```
12 06 2020; 17:57:04PM   Activity Log Started
12 06 2020; 17:57:04PM   Opened                              Project
C:\Users\mpatwal\AppData\Local\NASA\DAS3.1.0\
12 06 2020; 17:58:50PM   Science   and   Engineering   -   Orbit
Lifetime/Dwell Time

**INPUT**

     Start Year = 2021.200000 (yr)
     Perigee Altitude = 550.000000 (km)
     Apogee Altitude = 550.000000 (km)
     Inclination = 45.000000 (deg)
     RAAN = 0.000000 (deg)
     Argument of Perigee = 0.000000 (deg)
     Area-To-Mass Ratio = 0.038500 (m^2/kg)

**OUTPUT**

     Orbital Lifetime from Startyr = 3.701574 (yr)
     Time Spent in LEO during Lifetime  = 3.701574 (yr)
     Last year of Propagation = 2024 (yr)
     Returned Error Message: Object reentered
12 06 2020; 18:00:34PM   Science      and      Engineering      -
Apogee/Perigee History for a Given Orbit

**INPUT**

     Perigee Altitude = 550.000000 (km)
     Apogee Altitude = 550.000000 (km)
     Inclination = 45.000000 (deg)
     RAAN = 0.000000 (deg)
     Argument of Perigee = 0.000000 (deg)
     Mean Anomaly = 0.000000 (deg)
     Area-To-Mass Ratio = 0.038500 (m^2/kg)
     Start Year = 2021.200000 (yr)
     Integration Time = 5.000000 (yr)
```

OUTPUT

Plot