Orbital Debris Assessment Report

Produced by Care Weather Technologies, Inc. for the Veery-0F Mission

In Accordance with NASA-STD 8719.14A

CAREWEATHER

Revision History and Signatures

Revision	Notes	Produced By	Date
A	First Version	 Patrick Walton CEO, Care Weather Veery Mission Manager	4/16/2024

Summary of Compliance

Sections 1 through 8 of Process for Limiting Orbital Debris, NASA-STD-8719.14A 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-0F 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-0F mission.

Section 1: Mission Overview

The primary objective of the Veery-0F mission is to build on the success of Care Weather's past missions by testing the performance of updated and novel Care Weather small satellite bus and radar technologies. These technologies include an enhanced, low-noise radar system for ocean surface wind measurement, Earth-pointing control software, and a shape-memory deployment actuator. Instrumentation onboard the satellite will measure the performance of these systems, with data transmitted to the ground over the Iridium satellite network using an Iridium 9603 satellite modem. Veery-0F serves as a precursor for the future Veery scatterometer constellation, designed to fill critical gaps in U.S. scatterometer ocean vector wind weather data. The resulting data of this future constellation will provide unprecedented insight into tropical convection, enabling next-generation forecasts with accelerated early warnings for the nation's most costly disasters.

Section 2: Spacecraft Description

Veery-0F uses a 1U Cubesat form factor with rails and includes solar panels to decrease its orbital life as shown in Fig. 1. Veery-0F uses a shape-memory-alloy deployment actuator to release its tape spring antenna. Its maximum dimensions are 113mm x 136mm x 280mm.

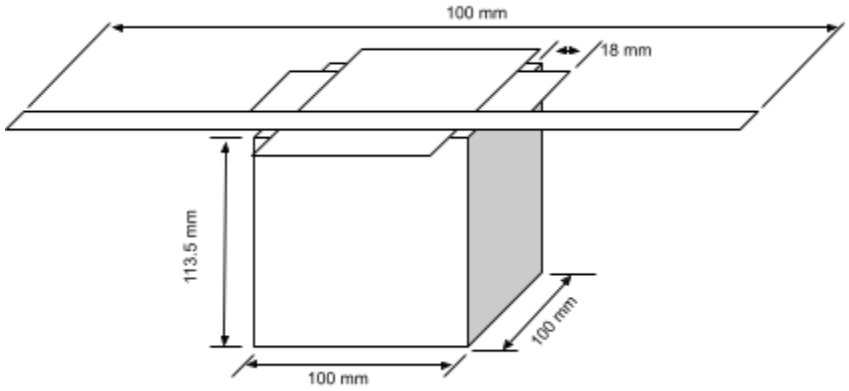

Figure 1. Geometry of Veery-0F

Hazards

Veery-0F has no pressure vessels, hazardous materials, or exotic materials.

Batteries

Veery-0F uses Lithium batteries managed by protective control circuitry. The battery control circuitry has an extensive suite of protections that have been flight proven on the Care Weather's past satellites, including:

1. Protection from over-charge voltage: The battery charge controller has a maximum output voltage setting. When the batteries reach this float voltage, the charger directs current to the satellite system bypassing the batteries and preventing overcharging. A 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 has a maximum charge current setting which is set to half the maximum charge current for the batteries.

3. Protection from over-discharge current or short circuits: The high-side enable switch limits current draw to within the current capacity of the batteries. In addition to this, a low side protection circuit disables the batteries instantly if an extreme current draw is reached.

4. Protection from under-voltage: The low side circuit protection disables the batteries when voltage drops too near to the minimum battery voltage. Hysteresis is implemented to not release this error state until the batteries reach 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: Lithium batteries become less efficient at colder temperatures. This causes them to produce excess waste heat, thereby increasing the minimum temperature. This is a self-stabilizing condition. With our past satellite missions, we have observed reliable battery performance even at near-freezing temperatures.

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." Since the orbital

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-D for the DAS activity log, which shows that the maximum probability of an on orbit collision is “3.6915E-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
Veery-0F is planned for flight in a sun-synchronous low-Earth orbit (<590 km). Planning for spacecraft maneuvers to accomplish post-mission disposal is not applicable. Disposal is achieved via passive atmospheric reentry. As seen below, the time until demise is assured to be under the 5-year rule.

Summary of DAS 3.2.6 Orbital Lifetime Calculations

DAS inputs are: 590 km (maximum possible) circular orbit, with an inclination of 97° at deployment no earlier than October 1, 2024. At the end of Veery-0F's mission, the satellite will passively drag stabilize in the highest drag configuration, resulting in a time until demise of 4.5 years, as shown in Fig. 3. This drag configuration was used for Care Weather's first satellite, Veery-RL1, and the altitude history of the satellite matched our original prediction modeled in DAS.

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

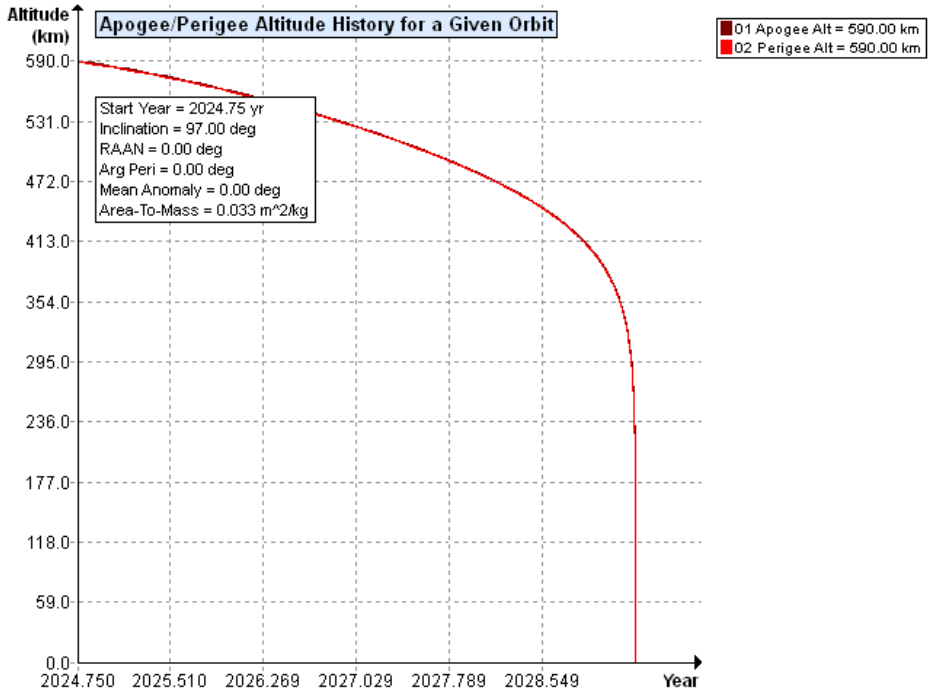

Figure 2. Altitude vs. Time For Veery-0F Spacecraft Starting at 590 km Orbit. Obtained Using NASA DAS 3.2.6. See Appendix A for More Details.

Section 7: Assessment of Spacecraft Re-entry Hazards

A detailed assessment of the components of the spacecraft was performed using DAS 3.2.6, to verify Requirement 4.7-1. See Appendix A, the DAS Activity Log, for more details. The

probability of human casualty is 0, thus Veery-0F 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. Markyn GMB, "Product Specification for Li-Ion Polymer Battery, Model 553448," 27 October 2016.

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

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

Appendix A: Activity Log From NASA Debris Assessment Software (DAS 3.2.6) for a 590 km Orbit

```
04 16 2024; 19:11:44PM   Activity Log Started
04 16 2024; 19:11:44PM   Opened                              Project
C:\Users\mpatr\OneDrive\Documents\GitHub\veery\licensing\DAS\
04 16 2024; 19:13:40PM   Processing Requirement 4.3-1: Return
Status :  Not Run

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

=============== End of Requirement 4.3-1 ===============
04 16 2024; 19:13:43PM   Processing  Requirement  4.3-2:  Return
Status : Passed

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

=============== End of Requirement 4.3-2 ===============
04 16 2024; 19:19:17PM   Processing Requirement 4.5-1: Return
Status :  Passed

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

**INPUT**

     Space Structure Name = Veery-0F
     Space Structure Type = Payload
     Perigee Altitude = 590.000 (km)
     Apogee Altitude = 590.000 (km)
     Inclination = 97.000 (deg)
```

```
     RAAN = 0.000 (deg)
     Argument of Perigee = 0.000 (deg)
     Mean Anomaly = 0.000 (deg)
     Final Area-To-Mass Ratio = 0.0330 (m^2/kg)
     Start Year = 2024.750 (yr)
     Initial Mass = 0.950 (kg)
     Final Mass = 0.950 (kg)
     Duration = 2.000 (yr)
     Station-Kept = False
     Abandoned = True
     Long-Term Reentry = False

**OUTPUT**

     Collision Probability = 3.6915E-07
     Returned Message: Normal Processing
     Date Range Message: Normal Date Range
     Status = Pass

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

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

04 16 2024; 19:20:18PM   Processing Requirement 4.6    Return
Status :  Passed

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

**INPUT**

     Space Structure Name = Veery-0F
     Space Structure Type = Payload

     Perigee Altitude = 590.000000 (km)
```

```
     Apogee Altitude = 590.000000 (km)
     Inclination = 97.000000 (deg)
     RAAN = 0.000000 (deg)
     Argument of Perigee = 0.000000 (deg)
     Mean Anomaly = 0.000000 (deg)
     Area-To-Mass Ratio = 0.033000 (m^2/kg)
     Start Year = 2024.750000 (yr)
     Initial Mass = 0.950000 (kg)
     Final Mass = 0.950000 (kg)
     Duration = 2.000000 (yr)
     Station Kept = False
     Abandoned = True
     PMD Perigee Altitude = 535.769576 (km)
     PMD Apogee Altitude = 536.124301 (km)
     PMD Inclination = 96.930670 (deg)
     PMD RAAN = 292.994834 (deg)
     PMD Argument of Perigee = 122.864813 (deg)
     PMD Mean Anomaly = 0.000000 (deg)
     Long-Term Reentry = False

**OUTPUT**

     Suggested Perigee Altitude = 535.769576 (km)
     Suggested Apogee Altitude = 536.124301 (km)
     Returned Error Message = Passes LEO reentry orbit criteria.

     Released Year = 2029 (yr)
     Requirement = 61
     Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
04 16 2024; 19:20:31PM   *********Processing Requirement 4.7-1
     Return Status :  Passed
```

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

name = Veery-0F
quantity = 1
parent = 0
materialID = 23
type = Box
Aero Mass = 0.950000
Thermal Mass = 0.950000
Diameter/Width = 0.100000
Length = 0.113000
Height = 0.100000

name = Body-mounted solar panels
quantity = 5
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.080000
Length = 0.100000

name = Chassis Rails and Crossbars
quantity = 12
parent = 1
materialID = 5
type = Box
Aero Mass = 0.028000
Thermal Mass = 0.028000
Diameter/Width = 0.010000
Length = 0.100000
Height = 0.010000

name = Batteries
```

```
quantity = 3
parent = 1
materialID = 5
type = Cylinder
Aero Mass = 0.020000
Thermal Mass = 0.020000
Diameter/Width = 0.010000
Length = 0.090000

name = Circuit Boards
quantity = 6
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.090000
Length = 0.090000

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

name = Reaction Wheels
quantity = 3
parent = 1
materialID = 5
type = Cylinder
Aero Mass = 0.020000
Thermal Mass = 0.020000
```

```
Diameter/Width = 0.030000
Length = 0.010000

name = Deployed solar panels
quantity = 4
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.015000
Thermal Mass = 0.015000
Diameter/Width = 0.080000
Length = 0.090000

name = Reaction wheel motors
quantity = 3
parent = 1
materialID = 57
type = Cylinder
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.020000
Length = 0.020000

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

name = Veery-0F
Demise Altitude = 77.993483
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Body-mounted solar panels
Demise Altitude = 76.882727
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
**************************************
name = Chassis Rails and Crossbars
Demise Altitude = 76.479610
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

**************************************
name = Batteries
Demise Altitude = 76.339309
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

**************************************
name = Circuit Boards
Demise Altitude = 76.837668
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

**************************************
name = Fasteners
Demise Altitude = 77.443003
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

**************************************
name = Reaction Wheels
Demise Altitude = 74.654922
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

**************************************
name = Deployed solar panels
Demise Altitude = 77.625368
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
************************************
name = Reaction wheel motors
Demise Altitude = 72.494711
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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

=============== End of Requirement 4.7-1 ===============
04 16 2024; 19:20:31PM   Project Data Saved To File
04 16 2024; 19:20:44PM   Science      and      Engineering      -
Apogee/Perigee History for a Given Orbit

**INPUT**

     Perigee Altitude = 590.000000 (km)
     Apogee Altitude = 590.000000 (km)
     Inclination = 97.000000 (deg)
     RAAN = 0.000000 (deg)
     Argument of Perigee = 0.000000 (deg)
     Mean Anomaly = 0.000000 (deg)
     Area-To-Mass Ratio = 0.032947 (m^2/kg)
     Start Year = 2024.750000 (yr)
     Integration Time = 10.000000 (yr)

**OUTPUT**

     Plot
04 16 2024; 19:20:48PM   Science   and   Engineering   -   Orbit
Lifetime/Dwell Time

**INPUT**

     Start Year = 2024.750000 (yr)
     Perigee Altitude = 590.000000 (km)
```

```
     Apogee Altitude = 590.000000 (km)
     Inclination = 96.500000 (deg)
     RAAN = 0.000000 (deg)
     Argument of Perigee = 0.000000 (deg)
     Area-To-Mass Ratio = 0.032947 (m^2/kg)

**OUTPUT**

     Orbital Lifetime from Startyr = 4.566829 (yr)
     Time Spent in LEO during Lifetime  = 4.566829 (yr)
     Last year of Propagation = 2029 (yr)
     Returned Error Message: Object reentered
```