Attachment 1

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
B	Updated components table, re-entry analysis, clarified drag panels	Patrick Walton CEO, Care Weather Veery Mission Manager	Alex Laraway CTO, Care Weather Veery System Engineer	02/02/2021
C	Corrected area-to-mass ratio typo, clarified area-to-mass calculation, re-ran re-entry debris analysis	Patrick Walton CEO, Care Weather Veery Mission Manager	Alex Laraway CTO, Care Weather Veery System Engineer	02/10/2021
D	Updated under-temperature protection to reflect final build.	Patrick Walton CEO, Care Weather Veery Mission Manager	Alex Laraway CTO, Care Weather Veery System Engineer	08/14/2021

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, and enable next-generation forecasts, accelerating early warnings for our nation's most costly disasters.

Section 2: Spacecraft Description

Veery-RL1 uses a 1U Cubesat form factor with rails and incorporates drag panels to decrease its orbital life as shown in Fig. 1. Its maximum dimensions are 113mm x 280mm x 280mm. Four polycarbonate drag panels measuring 8 cm x 9 cm are deployed from Veery using a "whip" deployment method in which the panels are constrained by the walls of the RocketLab Maxwell deployer. This results in an automatic release of the drag panels upon deployment. Accordingly, the drag panels deploy when the satellite deploys and there will be no stowed configuration on orbit outside of the satellite dispenser.

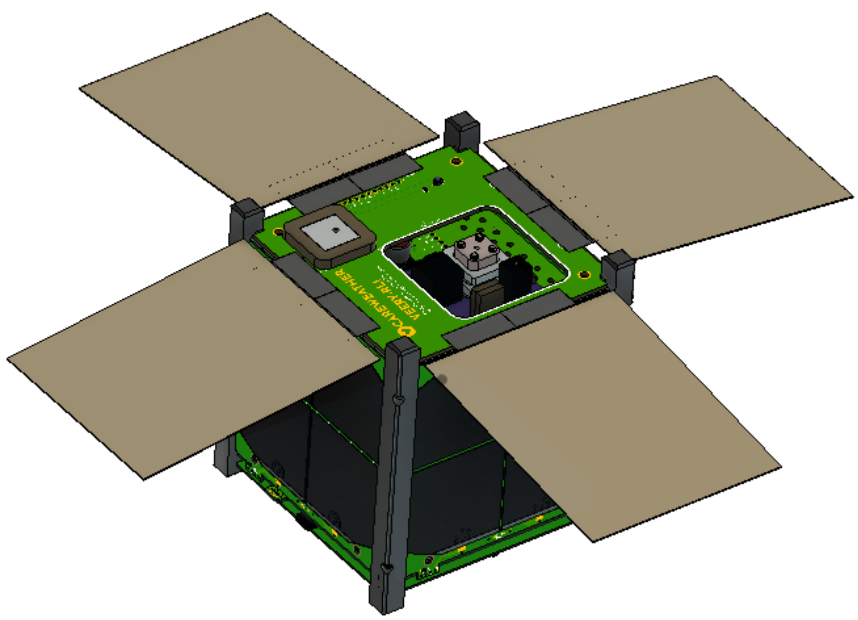

Figure 1. Veery-RL1 1U CubeSat with whip-deployed drag panels. The maximum envelope of the satellite, including the whip-deployed drag panels, is 113mm x 280mm x 280mm.

<u>Hazards</u>

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. We have observed excellent on-orbit battery performance on Veery RL1.

Each battery has protections against each possible method of failure, including

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: 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. We have observed a minimum on-orbit battery temperature of 10 deg Fahrenheit accompanied by excellent battery system performance.

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 2.1395E-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 3.5 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
The satellite mass is 0.888 kg. Due to the drag panels the center of pressure will be behind the center of mass, leading the satellite to stabilize aerodynamically in the direction of greatest drag, with the drag panels normal to the flight direction. Thus, the drag area is the area of the CubeSat face (0.1 m * 0.1 m) plus the area of a four drag panels (4 * 0.08 m * 0.09 m): 0.1 * 0.1+4 * 0.08 * 0.09 = 0.0388 m^2. The area-to-mass ratio of the satellite is then 0.0388 m^2 / 0.888 kg = 0.044 m^2/kg.

This area-to-mass ratio was used in DAS to simulate the orbital life of the spacecraft. Additional DAS inputs are: 550 km circular orbit, with an inclination of 45° at deployment no earlier than March 16, 2021. The lifetime of the spacecraft is estimated to be approximately 3.5 years until demise, as shown in Fig. 2.

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

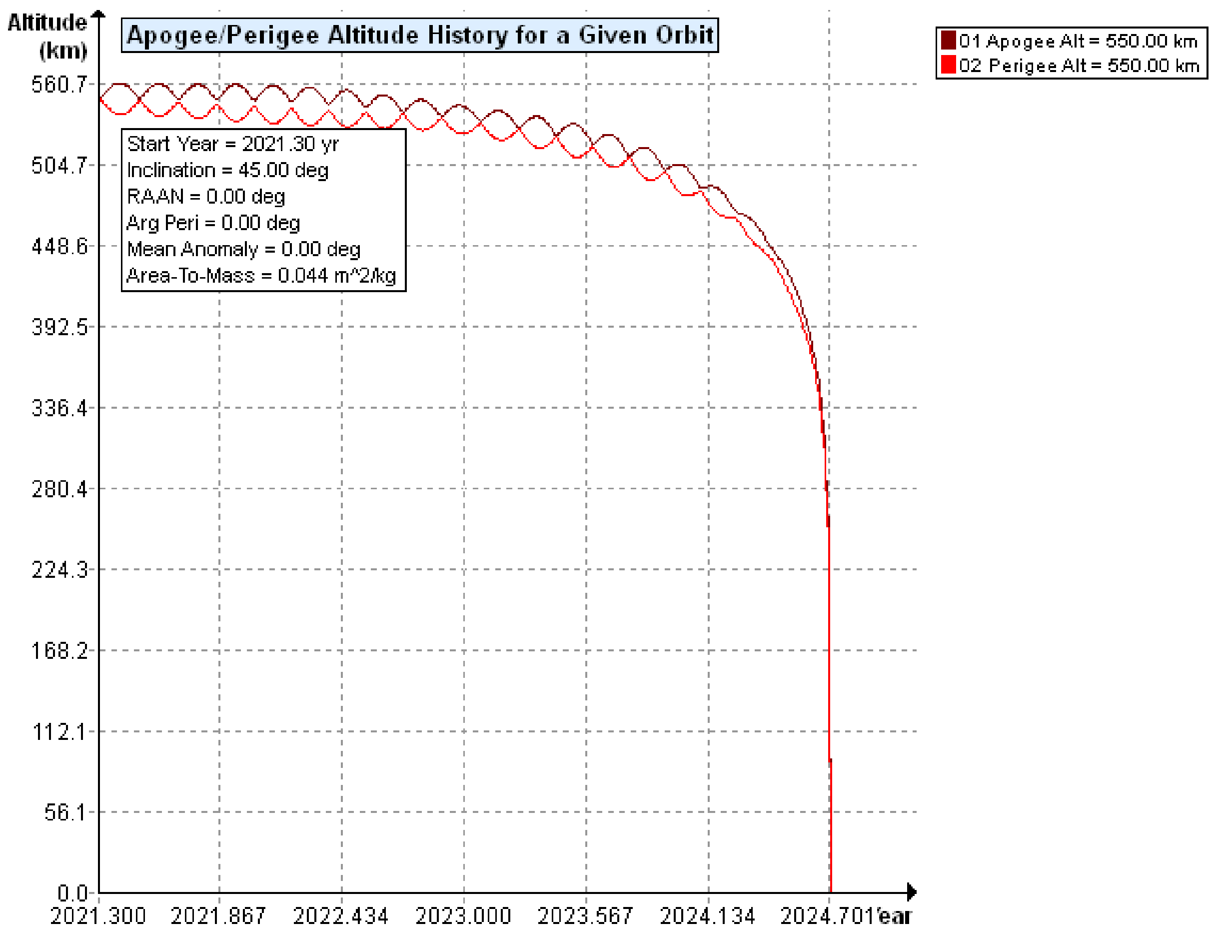

Figure 2. Altitude vs. Time For Veery-RL1 Spacecraft Starting at 550 km Orbit. Obtained Using NASA DAS 3.1.0. See Appendix B for More Details.

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. 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)

```
02 02 2021; 17:51:22PM   Activity Log Started
02 02 2021; 18:09:10PM   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 = 0.0440 (m^2/kg)
     Start Year = 2021.300 (yr)
     Initial Mass = 0.888 (kg)
     Final Mass = 0.888 (kg)
     Duration = 0.500 (yr)
     Station-Kept = False
     Abandoned = True

**OUTPUT**

     Collision Probability = 2.1395E-07
     Returned Message: Normal Processing
     Date Range Message: Normal Date Range
     Status = Pass
```

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

02 02 2021; 18:14:28PM   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 = 0.044000 (m^2/kg)
     Start Year = 2021.300000 (yr)
     Initial Mass = 0.888000 (kg)
     Final Mass = 0.888000 (kg)
     Duration = 0.500000 (yr)
     Station Kept = False
     Abandoned = True
     PMD Perigee Altitude = 539.421398 (km)
     PMD Apogee Altitude = 556.236556 (km)
     PMD Inclination = 44.997361 (deg)
     PMD RAAN = 114.246335 (deg)
     PMD Argument of Perigee = 149.202886 (deg)
     PMD Mean Anomaly = 0.000000 (deg)
```

```
**OUTPUT**

     Suggested Perigee Altitude = 539.421398 (km)
     Suggested Apogee Altitude = 556.236556 (km)
     Returned Error Message = Passes LEO reentry orbit criteria.

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

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=============== End of Requirement 4.6 ===============
02 02 2021; 18:20:11PM   Activity Log Started
02 02 2021; 18:20:11PM   Opened                              Project
C:\Users\mpatwal\AppData\Local\NASA\DAS3.1.0\
02 02 2021; 18:20:15PM   Processing Requirement 4.6    Return
Status :  Passed

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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 = 0.044000 (m^2/kg)
     Start Year = 2021.300000 (yr)
     Initial Mass = 0.888000 (kg)
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```
     Final Mass = 0.888000 (kg)
     Duration = 0.500000 (yr)
     Station Kept = False
     Abandoned = True
     PMD Perigee Altitude = 539.421175 (km)
     PMD Apogee Altitude = 556.236315 (km)
     PMD Inclination = 44.997361 (deg)
     PMD RAAN = 114.246225 (deg)
     PMD Argument of Perigee = 149.202955 (deg)
     PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

     Suggested Perigee Altitude = 539.421175 (km)
     Suggested Apogee Altitude = 556.236315 (km)
     Returned Error Message = Passes LEO reentry orbit criteria.

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

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

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

02 11 2021; 11:26:48AM   *********Processing Requirement 4.7-1
     Return Status :  Passed

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

name = 1U CubeSat 1
quantity = 1
parent = 0
materialID = 77
type = Box
Aero Mass = 0.888000
```

```
Thermal Mass = 0.888000
Diameter/Width = 0.280000
Length = 0.280000
Height = 0.113000

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 = 0.023000
Thermal Mass = 0.023000
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 = 4
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.008000
Thermal Mass = 0.008000
Diameter/Width = 0.090000
Length = 0.090000

name = Fasteners
quantity = 20
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 = 13
type = Cylinder
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.030000
Length = 0.010000

name = Drag Panels
quantity = 4
parent = 1
materialID = 77
type = Flat Plate
Aero Mass = 0.010000
Thermal Mass = 0.010000
Diameter/Width = 0.080000
```

```
Length = 0.090000

name = Thruster Anode/Cathodes
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

name = Reaction Wheel Motors
quantity = 3
parent = 1
materialID = 54
type = Cylinder
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.020000
Length = 0.020000

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

name = 1U CubeSat 1
Demise Altitude = 77.992615
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Body-mounted Solar Panels
Demise Altitude = 73.996445
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
************************************
name = Chassis Rails and Crossbars
Demise Altitude = 72.526230
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Batteries
Demise Altitude = 72.115685
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Circuit Boards
Demise Altitude = 77.202827
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Fasteners
Demise Altitude = 0.000000
Debris Casualty Area = 7.276095
Impact Kinetic Energy = 0.010249

************************************
name = Reaction Wheels
Demise Altitude = 68.533173
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Drag Panels
Demise Altitude = 77.747421
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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

```
name = Thruster Anode/Cathodes
Demise Altitude = 73.429573
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Reaction Wheel Motors
Demise Altitude = 55.305790
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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

=============== End of Requirement 4.7-1 ===============
02 11 2021; 11:26:48AM   Project Data Saved To File
```

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

```
02 02 2021; 17:19:19PM   Activity Log Started
02 02 2021; 17:19:19PM   Opened Project C:\Users\mpatwal\AppData\Local\NASA\DAS3.1.0\
02 02 2021; 17:21:23PM   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 = 0.044000 (m^2/kg)

**OUTPUT**
     Orbital Lifetime from Startyr = 3.477070 (yr)
     Time Spent in LEO during Lifetime  = 3.477070 (yr)
     Last year of Propagation = 2024 (yr)
     Returned Error Message: Object reentered
```

02 02 2021; 17:25:13PM   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 = 0.044000 (m^2/kg)
Start Year = 2021.300000 (yr)
Integration Time = 10.000000 (yr)

OUTPUT

Plot