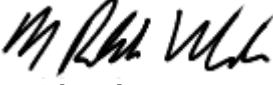
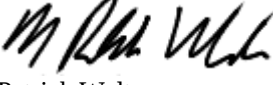


# **Orbital Debris Assessment Report**

**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                                                                                          | <br>Patrick Walton<br>CEO, Care Weather<br>Veery Mission Manager | <br>Alex Laraway<br>CTO, Care Weather<br>Veery System Engineer | 12/06/2020 |
| B        | Updated components table, re-entry analysis, clarified drag panels                                     | <br>Patrick Walton<br>CEO, Care Weather<br>Veery Mission Manager | <br>Alex Laraway<br>CTO, Care Weather<br>Veery System Engineer | 02/02/2021 |
| C        | Corrected area-to-mass ratio typo, clarified area-to-mass calculation, re-ran re-entry debris analysis | <br>Patrick Walton<br>CEO, Care Weather<br>Veery Mission Manager | <br>Alex Laraway<br>CTO, Care Weather<br>Veery System Engineer | 02/10/2021 |

## 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             |                                                 |

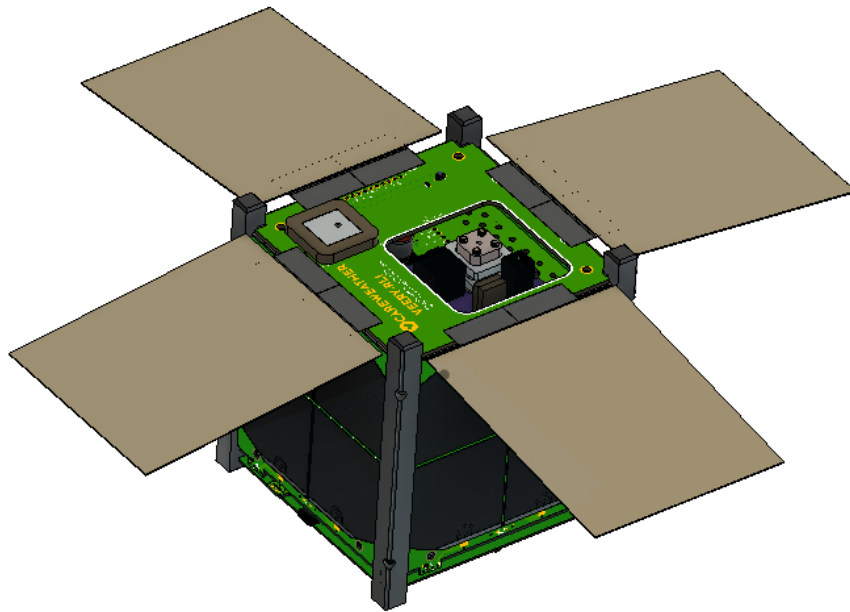
This report is intended to satisfy the orbital debris requirements listed in NASA Procedural Requirements for Limiting Orbital Debris Generation, NPR 8715.6A, 5 February 2008, for the Veery-RL1 mission.

## 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.**

## 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 2.1395E-07. This satisfies the 0.001 maximum probability requirement 4.5-1.

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**

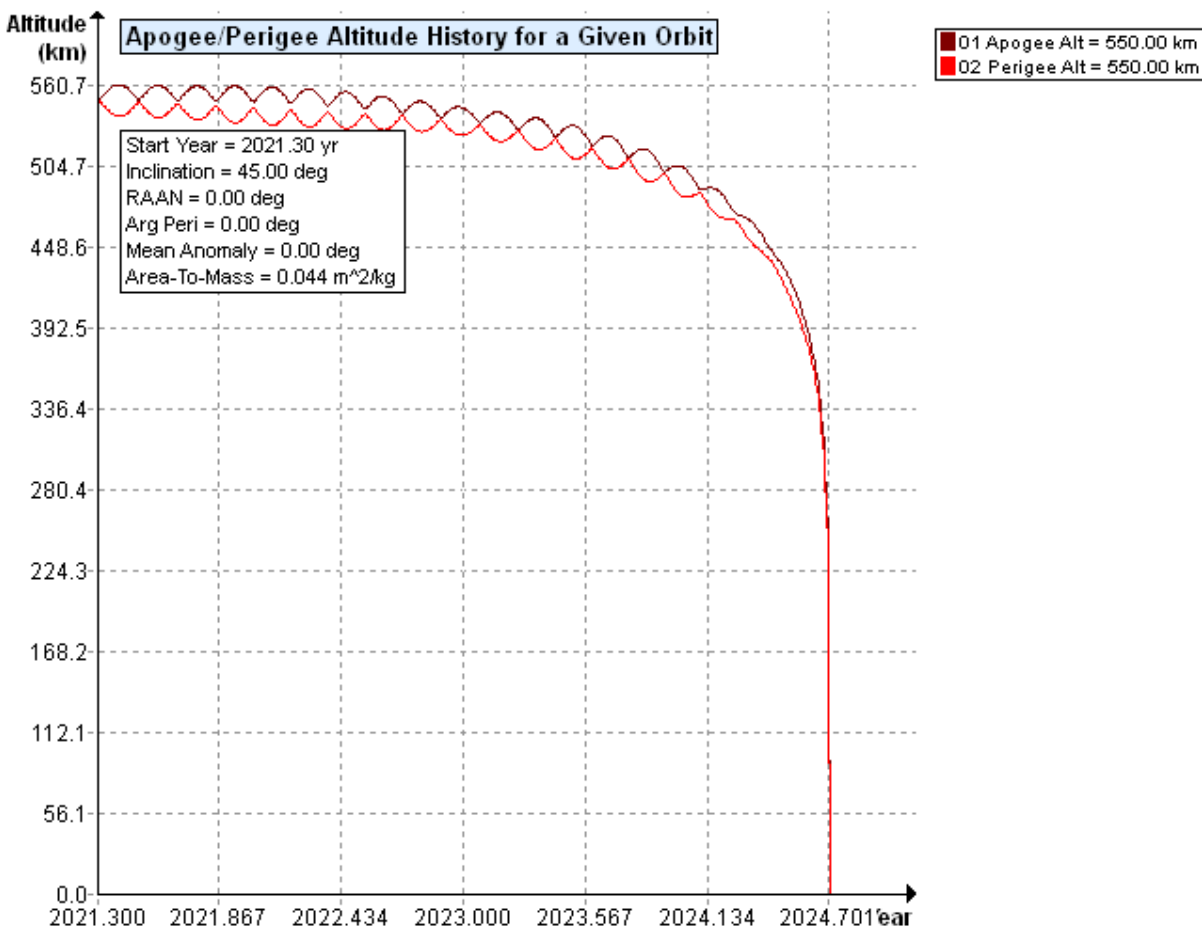
Planning for spacecraft maneuvers to accomplish post-mission disposal is not applicable. Disposal is achieved via passive atmospheric reentry. Veery's orbit will naturally decay due to atmospheric drag until it re-enters the atmosphere 3.5 years after it is released on orbit. This is well under the 25-year rule of requirement 4.6-1.

##### 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 ( $0.1 \text{ m} * 0.1 \text{ m}$ ) plus the area of a four drag panels ( $4 * 0.08 \text{ m} * 0.09 \text{ m}$ ):  $0.1 * 0.1 + 4 * 0.08 * 0.09 = 0.0388 \text{ m}^2$ . The area-to-mass ratio of the satellite is then  $0.0388 \text{ m}^2 / 0.888 \text{ kg} = 0.044 \text{ m}^2/\text{kg}$ .

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<sup>2</sup>/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

=====

===== 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<sup>2</sup>/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

=====

===== 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

=====

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<sup>2</sup>/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 = 539.421175 (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<sup>2</sup>/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<sup>2</sup>/kg)  
Start Year = 2021.300000 (yr)  
Integration Time = 10.000000 (yr)

**\*\*OUTPUT\*\***

Plot