Orbital Debris Assessment Report

Challenger

per NASA-STD 8719.14A

Signature Page

4/1/2021

Joseph Latrell, President
Mini-Cubes, LLC

3/31/2021

Michael L. Miller, Licensing Coordinator
Sterk Solutions Corp.

3/31/2021

Mike H. Miller, Licensing Analyst
Sterk Solutions Corp.

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 Challenger 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 Challenger through ChallengerI spacecraft. They all are 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 Challenger mission, operated by MiniCubes, LLC, is to develop a space based method to distribute secure system keys (SSH keys) for Internet of Things devices.

The satellite will be launched as a secondary payload carried by the Momentus Vigoride vehicle aboard SpaceX Falcon 9, from Vandenburg AFB, currently scheduled for June 2021. It will be deployed from the Momentus Vigoride into a Sun-synchronous circular orbit, altitude 550 km, orbital inclination 97.59 degrees. Transmission will begin upon deploy into orbit, and cease 2 years later. Atmospheric friction will slow the satellite and reduce the altitude of the orbit, until de-orbiting is estimated to occur 4.4 years after launch.

Challenger will be deployed from Fossa Systems PocketPod deployer mounted on the Vigoride vehicle. The spacecraft will deploy after the activation signal is initiated by the Vigoride, causing the deployer door to open which will allow the spacecraft contained therein to exit, pushed gently out by the spring loaded push plate inside the deployer. The deployment switch on board each satellite, will activate the solar detection system. About 30 seconds after solar detection, the power up sequence begins. See Schedule 1 for a step by step description of the deploy sequence.

Challenger Deployment CONOPS	
Timing	**Event**
Deploy of Challenger	Electrical Power System (EPS) Solar Detector Enabled via Deployment Switch
30 sec After Solar Detection (ASD)	EPS Power Up
2 min ASD	Flight Computer Power Up
15 min ASD	Deployment of Solar Arrays and Antennas
17 min ASD	Payload Power Up
30 min ASD	Beacon Transmission Starts (30 sec every 5 min)
72 hours ASD	Beacon Transmission Ends
72 hours 5 min ASD	Payload Transmission Begins

Schedule 1 Challenger Deployment Schedule and CONOPS

Section 2: Spacecraft Description

The spacecraft is a 3p pocketqube with deployable elements. Measurements after deployment of the solar panels and antennas are 19.2 cm X 14.5 cm X 24.4 cm. The total mass is about 0.639 Kg.

Figure 1 shows the design of the satellite.

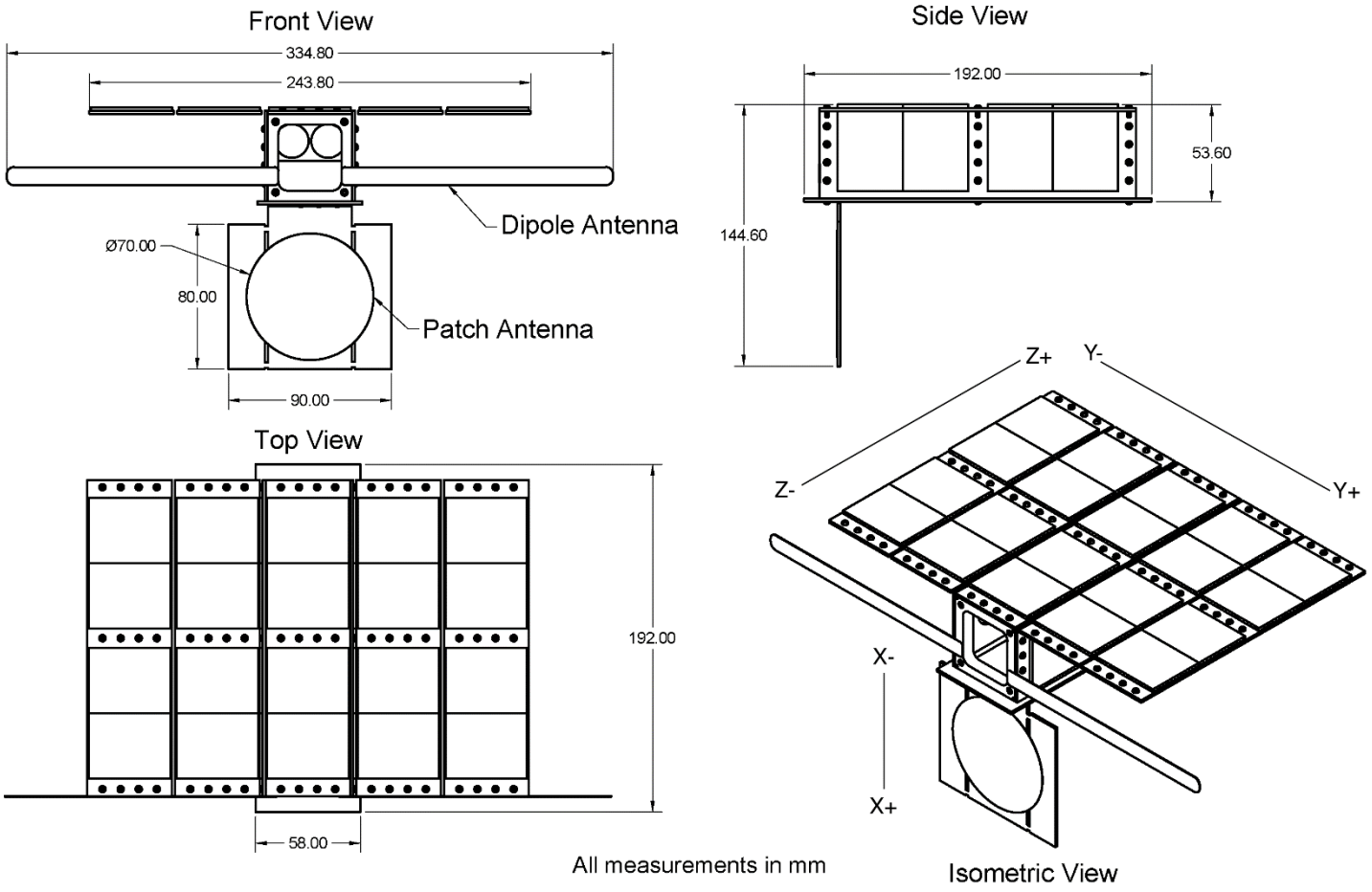

Figure 1 Challenger Design

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

Two (2) 18560 Lithium Ion batteries (LG INR18650HG2) are mounted in tandem to a thermal plate. This plate is connected to the OBC to allow heat dissipation from the CPU to the warm the batteries.

The two cells together store a total of 6000 mAh at 3.6 volts. The UL file listing number of the battery is MH19896. They are used with a battery circuit protection module providing over-charge/over-current protection and over-discharge circuitry.

The battery and power system have been tested under vacuum conditions for a duration of not less than 12 hours. Also, the system has undergone GEVs 7000 environmental testing.

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.

Assessment of spacecraft compliance with Requirements 4.4-1 through 4.4-4 shows that the Challenger is 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 0.0149 m^2.

With mass of 0.639 kg, the area to mass ratio in the stabilized attitude is 0.0234 m^2/kg.

From DAS, the orbit lifetime will be 4.41 years and probability of collision with space objects larger than 10 *cm* in diameter during the orbital lifetime of the spacecraft, is 1.7631e-07.

Case 2: Deployed and Tumbling

A deployed, tumbling Challenger 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 0.0347 m^2. The Area to mass ratio is therefore 0.0543 m^2/kg. From DAS, the orbit lifetime is 2.84 years, and the probability of collision with space objects larger than 10 *cm* in diameter during the orbital lifetime of the spacecraft, is 2.9385e-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 0.0031 m^2, and an area to mass ratio of 0.0049. From DAS, the orbit lifetime is 16.1 years, and the probability of collision with space objects larger than 10 *cm* in diameter during the orbital lifetime of the spacecraft, is 1.2709e-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 0.0474 m^2, and an area to mass ratio of 0.0742. From DAS, the orbit lifetime is 2.44 years, and the probability of collision with space objects larger than 10 *cm* in diameter during the orbital lifetime of the spacecraft, is 3.4316e-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 less than $3.432e^{-7}$ per DAS for any configuration. This satisfies the 0.001 maximum probability requirement 4.5-l. Thus DAS provides a "Passed" status for requirement 4.5-1.

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 version 3.1.2 Orbital Lifetime Calculations:

DAS inputs are: 550km perigee / 550 km apogee orbit, on an inclination from the equator of 97.59 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 approximately 16.1 years. There is no mode in which the spacecraft would be estimated to stay in orbit longer than that.

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 is does not consider any loss 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 only surviving component, the tape measure antenna, is described in Table 2.

Surviving Component	Original Mass, kg	Terminal Energy, Joules	Casualty Area, m^2
Tape Measure Antenna	**0.0025**	**0.046**	**0.838**

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. Since the only surviving component has a terminal energy of 0.046 Joules, very much less than 15 Joules, the Risk of Human Casualty is zero.

The spacecraft complies with the less than 1:10,000 probability of Human Casualty Requirement 4.7-1.

The Challenger thus is 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

```
03 31 2021; 09:47:58AM Activity Log Started
03 31 2021; 09:47:58AM Opened Project C:\Users\mille\Sterk\CHALLENGER
DAS\
03 31 2021; 10:45:59AM Mission Editor Changes Applied
03 31 2021; 10:45:59AM Project Data Saved To File
03 31 2021; 10:51:27AM Processing Requirement 4.5-1: Return Status :  Passed

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

**INPUT**

      Space Structure Name = Challenger
      Space Structure Type = Payload
      Perigee Altitude = 550.000 (km)
      Apogee Altitude = 550.000 (km)
      Inclination = 97.590 (deg)
      RAAN = 0.000 (deg)
      Argument of Perigee = 0.000 (deg)
      Mean Anomaly = 0.000 (deg)
      Final Area-To-Mass Ratio = 0.0234 (m^2/kg)
      Start Year = 2021.500 (yr)
      Initial Mass = 0.639 (kg)
      Final Mass = 0.639 (kg)
      Duration = 2.000 (yr)
      Station-Kept = False
      Abandoned = True

**OUTPUT**

      Collision Probability = 1.7631E-07
      Returned Message: Normal Processing
      Date Range Message: Normal Date Range
      Status = Pass

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

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

03 31 2021; 10:52:05AM Project Data Saved To File
03 31 2021; 10:52:10AM Requirement 4.5-2:  Compliant
=============== End of Requirement 4.5-2 ===============

03 31 2021; 10:53:29AM Processing Requirement 4.6 Return Status :  Passed

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

**INPUT**

      Space Structure Name = Challenger
```

```
      Space Structure Type = Payload

      Perigee Altitude = 550.000000 (km)
      Apogee Altitude = 550.000000 (km)
      Inclination = 97.590000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Area-To-Mass Ratio = 0.023400 (m^2/kg)
      Start Year = 2021.500000 (yr)
      Initial Mass = 0.639000 (kg)
      Final Mass = 0.639000 (kg)
      Duration = 2.000000 (yr)
      Station Kept = False
      Abandoned = True
      PMD Perigee Altitude = 531.733357 (km)
      PMD Apogee Altitude = 540.881055 (km)
      PMD Inclination = 97.619660 (deg)
      PMD RAAN = 0.180215 (deg)
      PMD Argument of Perigee = 29.266874 (deg)
      PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

      Suggested Perigee Altitude = 531.733357 (km)
      Suggested Apogee Altitude = 540.881055 (km)
      Returned Error Message = Passes LEO reentry orbit criteria.

      Released Year = 2025 (yr)
      Requirement = 61
      Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
03 31 2021; 10:53:29AM *********Processing Requirement 4.7-1
      Return Status :  Passed

***********INPUT****
 Item Number = 1
 name = Challenger quantity = 1
parent = 0 materialID = 50 type =
Box Aero Mass = 0.639000
Thermal Mass = 0.639000
Diameter/Width = 0.050000
Length = 0.192000
Height = 0.050000

name = Satellite Body quantity = 1
parent = 1 materialID = 50 type =
Box Aero Mass = 0.061000
Thermal Mass = 0.061000
Diameter/Width = 0.050000
Length = 0.192000
```

```
Height = 0.050000  name = Solar
Panel quantity = 5
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.046500
Thermal Mass = 0.046500
Diameter/Width = 0.046000
Length = 0.178000  name = Base
Plate quantity = 1 parent = 1
materialID = 23 type = Flat Plate
Aero Mass = 0.035000
Thermal Mass = 0.035000
Diameter/Width = 0.058000
Length = 0.192000  name = OBC
quantity = 1 parent = 1
materialID = 23 type = Flat Plate
Aero Mass = 0.010700
Thermal Mass = 0.010700
Diameter/Width = 0.040200
Length = 0.055000  name = Transceiver
Board quantity = 1 parent = 1
materialID = 23 type = Box Aero Mass
= 0.018000
Thermal Mass = 0.018000
Diameter/Width = 0.035000
Length = 0.065000
Height = 0.004500  name = Battery
Plate
quantity = 1
parent = 1
materialID = 8 type = Box Aero
Mass = 0.035000
Thermal Mass = 0.035000
Diameter/Width = 0.045000
Length = 0.065000
Height = 0.010000  name = Li-Ion
Battery
quantity = 2
parent = 1
materialID = 54 type = Cylinder
Aero Mass = 0.045800
Thermal Mass = 0.045800
Diameter/Width = 0.018300
Length = 0.065000  name = Antenna
quantity = 2
parent = 1
materialID = 54 type = Flat Plate
Aero Mass = 0.002500
Thermal Mass = 0.002500
Diameter/Width = 0.012500
Length = 0.178000  name = M2 x 6mm
Screws quantity = 48 parent = 1
materialID = 59 type = Cylinder
Aero Mass = 0.000100
Thermal Mass = 0.000100
Diameter/Width = 0.005000
```

```
Length = 0.006000  name = M2 x 10mm
Screws quantity = 12 parent = 1
materialID = 59 type = Cylinder Aero
Mass = 0.000200
Thermal Mass = 0.000200
Diameter/Width = 0.005000
Length = 0.010000  name = M2 x 8mm
Screws
quantity = 4
parent = 1
materialID = 59 type = Cylinder
Aero Mass = 0.000100
Thermal Mass = 0.000100
Diameter/Width = 0.005000
Length = 0.008000  name = Hinges
quantity = 8 parent = 1
materialID = 8 type = Box Aero
Mass = 0.010000
Thermal Mass = 0.010000
Diameter/Width = 0.010000
Length = 0.036000
Height = 0.010000  name = Knurls
quantity = 48 parent = 1
materialID = 59 type = Cylinder
Aero Mass = 0.000100
Thermal Mass = 0.000100
Diameter/Width = 0.003500
Length = 0.003500  name = RBF
Switch
quantity = 2
parent = 1
materialID = 23
type = Box
Aero Mass = 0.006000
Thermal Mass = 0.006000
Diameter/Width = 0.013000
Length = 0.026000
Height = 0.012000  name = Patch
Antenna quantity = 1 parent = 1
materialID = 19 type = Flat Plate
Aero Mass = 0.040000
Thermal Mass = 0.040000
Diameter/Width = 0.080000
Length = 0.090000  name =
magnetorquer
quantity = 2
parent = 1
materialID = 19 type = Cylinder
Aero Mass = 0.003000
Thermal Mass = 0.003000 Diameter/Width = 0.003500
Length = 0.040000

**************OUTPUT****
Item Number = 1
 name = Challenger Demise Altitude =
77.997993
Debris Casualty Area = 0.000000
```

```
Impact Kinetic Energy = 0.000000

************************************ name =
Satellite Body Demise Altitude = 77.768173
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************ name = Solar
Panel Demise Altitude = 77.045456
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************ name = Base
Plate Demise Altitude = 77.444229
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************ name = OBC
Demise Altitude = 77.345993
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************ name =
Transceiver Board Demise Altitude = 77.101418
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************ name =
Battery Plate Demise Altitude = 76.099144
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************ name = Li-
Ion Battery Demise Altitude = 70.693230
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************ name = Antenna Demise Altitude = 0.000000
Debris Casualty Area = 0.837658
Impact Kinetic Energy = 0.045817

************************************ name = M2 x
6mm Screws Demise Altitude = 77.796394
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************ name = M2 x
10mm Screws Demise Altitude = 77.704872
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************ name = M2 x
8mm Screws Demise Altitude = 77.830345
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
************************************ name =
Hinges Demise Altitude = 76.111214
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************ name =
Knurls Demise Altitude = 77.578384
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************ name = RBF
Switch Demise Altitude = 77.130005
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************ name = Patch
Antenna Demise Altitude = 76.829399
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************ name =
magnetorquer Demise Altitude = 77.048828
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************ ========== End of Requirement 4.7-1
==========
03 31 2021; 10:53:29AM Project Data Saved To File
03 31 2021; 14:48:29PM Science and Engineering - Orbit Lifetime/Dwell
Time

**INPUT**

      Start Year = 2021.500000 (yr)
      Perigee Altitude = 550.000000 (km)
      Apogee Altitude = 550.000000 (km)
      Inclination = 97.590000 (deg)
      RAAN = 92.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Area-To-Mass Ratio = 0.023400 (m^2/kg)

**OUTPUT**

      Orbital Lifetime from Startyr = 4.407940 (yr)
      Time Spent in LEO during Lifetime  = 4.407940 (yr)
      Last year of Propagation = 2025 (yr)
      Returned Error Message: Object reentered
03 31 2021; 14:49:59PM Mission Editor Changes Applied
03 31 2021; 14:49:59PM Project Data Saved To File
03 31 2021; 14:54:02PM Processing Requirement 4.5-1: Return Status :  Passed

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

**INPUT**
```

```
      Space Structure Name = Challenger
      Space Structure Type = Payload
      Perigee Altitude = 550.000 (km)
      Apogee Altitude = 550.000 (km)
      Inclination = 97.590 (deg)
      RAAN = 0.000 (deg)
      Argument of Perigee = 0.000 (deg)
      Mean Anomaly = 0.000 (deg)
      Final Area-To-Mass Ratio = 0.0543 (m^2/kg)
      Start Year = 2021.500 (yr)
      Initial Mass = 0.639 (kg)
      Final Mass = 0.639 (kg)
      Duration = 2.000 (yr)
      Station-Kept = False
      Abandoned = True

**OUTPUT**

      Collision Probability = 2.9385E-07
      Returned Message: Normal Processing
      Date Range Message: Normal Date Range
      Status = Pass

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

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

03 31 2021; 14:54:29PM Project Data Saved To File
03 31 2021; 14:54:36PM Requirement 4.5-2:  Compliant
=============== End of Requirement 4.5-2 ===============

03 31 2021; 14:55:23PM Science and Engineering - Orbit Lifetime/Dwell
Time

**INPUT**

      Start Year = 2021.500000 (yr)
      Perigee Altitude = 550.000000 (km)
      Apogee Altitude = 550.000000 (km)
      Inclination = 97.590000 (deg)
      RAAN = 92.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Area-To-Mass Ratio = 0.054300 (m^2/kg)

**OUTPUT**

      Orbital Lifetime from Startyr = 2.841889 (yr)
      Time Spent in LEO during Lifetime  = 2.841889 (yr)
      Last year of Propagation = 2024 (yr)
      Returned Error Message: Object reentered
03 31 2021; 14:57:53PM Mission Editor Changes Applied
03 31 2021; 14:57:53PM Project Data Saved To File
03 31 2021; 15:15:57PM Processing Requirement 4.5-1: Return Status :  Passed
```

```
============== Run Data
==============

**INPUT**

      Space Structure Name = Challenger
      Space Structure Type = Payload
      Perigee Altitude = 550.000 (km)
      Apogee Altitude = 550.000 (km)
      Inclination = 97.590 (deg)
      RAAN = 0.000 (deg)
      Argument of Perigee = 0.000 (deg)
      Mean Anomaly = 0.000 (deg)
      Final Area-To-Mass Ratio = 0.0049 (m^2/kg)
      Start Year = 2021.500 (yr)
      Initial Mass = 0.639 (kg) Final Mass = 0.639
      (kg)
      Duration = 2.000 (yr)
      Station-Kept = False
      Abandoned = True

**OUTPUT**

      Collision Probability = 1.2709E-07
      Returned Message: Normal Processing
      Date Range Message: Normal Date Range
      Status = Pass

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

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

03 31 2021; 15:16:15PM Project Data Saved To File
03 31 2021; 15:16:20PM Requirement 4.5-2:  Compliant
=============== End of Requirement 4.5-2 ===============

03 31 2021; 15:16:45PM Science and Engineering - Orbit Lifetime/Dwell
Time

**INPUT**

      Start Year = 2021.500000 (yr)
      Perigee Altitude = 550.000000 (km)
      Apogee Altitude = 550.000000 (km)
      Inclination = 97.590000 (deg)
      RAAN = 92.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Area-To-Mass Ratio = 0.004900 (m^2/kg)

**OUTPUT**

      Orbital Lifetime from Startyr = 16.098563 (yr)
      Time Spent in LEO during Lifetime  = 16.098563 (yr)
```

```
      Last year of Propagation = 2037 (yr)
      Returned Error Message: Object reentered
03 31 2021; 15:25:53PM Mission Editor Changes Applied
03 31 2021; 15:25:53PM Project Data Saved To File
03 31 2021; 15:30:59PM Processing Requirement 4.5-1: Return Status :  Passed

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

**INPUT**

      Space Structure Name = Challenger Space Structure
      Type = Payload
      Perigee Altitude = 550.000 (km)
      Apogee Altitude = 550.000 (km)
      Inclination = 97.590 (deg)
      RAAN = 0.000 (deg)
      Argument of Perigee = 0.000 (deg)
      Mean Anomaly = 0.000 (deg)
      Final Area-To-Mass Ratio = 0.0742 (m^2/kg)
      Start Year = 2021.500 (yr)
      Initial Mass = 0.639 (kg)
      Final Mass = 0.639 (kg)
      Duration = 2.000 (yr)
      Station-Kept = False
      Abandoned = True

**OUTPUT**

      Collision Probability = 3.4316E-07
      Returned Message: Normal Processing
      Date Range Message: Normal Date Range
      Status = Pass

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

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

03 31 2021; 15:32:08PM Project Data Saved To File
03 31 2021; 15:32:13PM Requirement 4.5-2:  Compliant
=============== End of Requirement 4.5-2 ===============

03 31 2021; 15:32:27PM Science and Engineering - Orbit Lifetime/Dwell
Time

**INPUT**

      Start Year = 2021.500000 (yr)
      Perigee Altitude = 550.000000 (km)
      Apogee Altitude = 550.000000 (km)
      Inclination = 97.590000 (deg)
      RAAN = 92.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Area-To-Mass Ratio = 0.074200 (m^2/kg)
```

```
**OUTPUT**

      Orbital Lifetime from Startyr = 2.442163 (yr)
      Time Spent in LEO during Lifetime  = 2.442163 (yr)
      Last year of Propagation = 2023 (yr)
      Returned Error Message: Object reentered
```