


Exhibit A – Orbital Debris Assessment Report (“ODAR”)

Swarm Orbital Debris Assessment Report

SWARM TECHNOLOGIES MISSION PROFILE
PREPARED BY: SWARM TECHNOLOGIES INC
REVISION 1: May 1, 2020

ODAR Signature Approval

Program/ Project Manager	Sara Spangelo
Signature	
Date	May 1, 2020

ODAR Section 1: Program Management and Mission Overview

Program/Project Manager	Sara Spangelo
Mission Description	The purpose of the Swarm satellite constellation is to provide low-cost, global two-way communication services within the VHF band. Swarm proposes to provide these services by deploying a constellation consisting of up to 150 ¼U satellites.
Foreign Government Involvement	None
Project Milestones	The Swarm satellites will typically be launched 12 to 24 at a time from one or two 3U dispensers, dependent on launch availability and the orbital characteristics required to optimize system coverage. Swarm will deploy its constellation by launching its satellites as secondary payloads. Due to solar cycle variations, satellite lifetime is significantly coupled to launch date over an 11 year cycle. The orbit start date for this analysis has been set to maximize simulated orbital lifetime within the license period, in order to produce conservative object collision probabilities.
Proposed Launch Date:	
Proposed Launch Vehicles:	
Proposed Launch Sites:	
Launch Vehicle Operator:	Launches will be booked as they become available and are subject to schedule and orbital parameter changes. As a result, Swarm’s finalized list of launch dates and orbital parameters is not yet available. Swarm therefore requests authorization to deploy and subsequently replenish its constellation on launches with parameters within the following bounds:

- Inclination: equatorial (0 degrees) to polar sun-synchronous (98 degrees)
- Apogee: 300-585 km
- Perigee: 300-585 km

The table below is a notional allocation of altitudes and orbital inclinations for Swarm’s 150-satellite constellation and is representative of available launch opportunities in the desired timeframe.

# Satellites	Altitude [km]	Inclination [°]
12	585	45
12	585	10
126	585	97-98 (SSO)
Lower and upper bound	300-585	0-98

This ODAR analyzes a range of representative orbits. For the purposes of debris assessment, analysis was conducted with the “worst-case” altitude (585 km) in all cases to assess the maximum collision probability over the lifetime of the satellites. Rather than relying on analytic estimates, the effective area-to-mass ratios of the satellites were derived empirically from radar measurements of the orbital altitude history over time for the first four Swarm satellites in LEO, which are also ¼U in size and have a similar, passively-stabilized flight configuration. This process is detailed in Section 6. These area-to-mass ratios accurately represent both operational and non-operational satellites, as passive stability is the primary flight mode in both cases. Active maneuvering capabilities are reserved for collision avoidance, accelerated deorbit, and phase adjustments.

The aggregate collision probability for all Swarm satellites launched over the 15-year period of the requested grant is also calculated.

Mission Duration:

The operational lifetime of the hardware for each satellite is designed to be up to 20 years following deployment from the launch vehicle. The orbital lifetime for the satellites at 585 km may range from 2.1 to 7.9 years over the requested grant period, due to varying solar influence on the Earth’s atmosphere, described in Section 6. The satellite hardware design therefore has a margin of safety of 2.5x to 9.5x the orbital lifetime.

Launch /
Deployment Profile:

Launch

The Swarm satellites will be injected directly into the target orbits outlined above.

Checkout

For up to 1 month following deployment into orbit, the Swarm satellites will remain in checkout phase. During this phase, ground operators will verify correct operation of the satellites and their payloads, and prepare them for the operational phase.

	<p>Operations The operational phase of the satellite begins following the successful deployment of the Swarm satellites from the launch vehicle and successful checkout.</p> <p>Post-mission Disposal Following the end of the operational phase, the satellites will remain on orbit in a non-transmitting mode while the orbit of the satellites passively decays until the satellites reenter the atmosphere and disintegrate. The satellites are nominally expected to reenter the atmosphere 2.1 to 7.9 years following deployment from the launch vehicle. Swarm also retains the ability to de-orbit the satellites using the onboard propulsion system and will do so to the extent that is practical, and will coordinate such maneuvers with CSpOC. Swarm will provide its maneuvering plans to other satellite operators upon request.</p>
Selection of Orbit:	The selection of the chosen orbits was made based on available launch opportunities, orbital lifetime and collision considerations, and system requirements.
Potential Physical Interference with Other Orbiting Object:	<p>The satellite orbits will naturally decay following deployment from the launch vehicle.</p> <p>As detailed in Section 5, the probability of physical interference between the satellites and other space objects is sufficiently unlikely that the satellites comply with Requirement 4.5. To be conservative, the propulsion system was not used to reduce orbital lifetime in these physical interference calculations.</p>

ODAR Section 2: Spacecraft Description

Physical Description:

Property	Value
Total Mass at Launch	0.60 kg
Dry Mass at Launch	0.55 kg
Form Factor	¼U satellite
COG	0.60 kg satellite: <X1,Y1,Z1> = <0, 16.5, -1.5> [mm] relative to center
Envelope (stowed)	118mm x 118mm x 28mm
Envelope (deployed)	118mm x 118mm x 28mm Deployed antennas are 1084 mm tip to tip

Propulsion Systems	Swarm will fly a dual mode cold gas / electric propulsion system on its satellites. For conservatism, the propulsion system ¹ is not used in the ODAR modeling to accelerate or slow the decay of the orbital lifetime of the satellites, nor to reduce the modeled collision risk of the individual satellites or that of the constellation as an aggregate.
Fluid Systems	The onboard propellant is a non-toxic green propellant that is stored in a non-pressurized propellant reservoir. The propellant exists in a gaseous state in the vacuum of space, and does not become “persistent droplets” nor persistent solids in the vacuum of space. The entire propulsion system will be tested at Swarm and by the Aerospace Corporation (or similarly qualified laboratory), and will be qualified by Swarm prior to flight.
ADCS	GPS, 9 DOF IMU, magnetometer, magnetorquer system for attitude control
Range Safety/ Pyrotechnic Devices	None
Electrical Generation	Solar cells
Electrical Storage	Rechargeable lithium-ion battery. Qty 1: 18650 cell.
Radioactive Materials	None

ODAR Section 3: Assessment of Debris Released During Normal Operations

Objects larger than 1mm expected to be released during orbit:	None
Rationale for release of each object:	N/A
Time of release of each object:	N/A
Release velocity of each object:	N/A
Expected orbital parameters of each object:	N/A
Calculated orbital lifetime of each object:	N/A

Assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2:	
4.3-1, Mission-Related Debris Passing Through LEO:	COMPLIANT

¹ The Swarm satellite propulsion systems employ a dual mode cold gas / electric propulsion thruster, and have a single propellant reservoir. The non-toxic green propellant is stored as in a non-pressurized propellant reservoir, and expelled as a cold gas or plasma. There is no possibility of persistent droplets nor persistent solids, as the propellant exists in the gaseous phase in the vacuum of space.

4.3-2, Mission-Related Debris Passing Near GEO:	COMPLIANT
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A DAS 3.0 log demonstrating the compliance to the above requirements is available in Appendix A – “DAS 3.0 Log”.

ODAR Section 4: Assessment of Spacecraft Intentional Breakups and Potential for Explosions

Potential causes for spacecraft breakup (there is only one plausible causes for breakup of the satellites):

- Energy released from onboard Lithium-ion battery from the unlikely event of overcharging or shorts

Summary of failure modes and effects analysis of all credible failure modes which may lead to an accidental explosion:

The battery aboard the satellite is a 11 Whr Lithium-Ion battery, which represents the only credible failure mode during which stored energy is released. The main failure modes associated with Lithium Ion batteries result from overcharging, over-discharging, internal shorts, and external shorts.

The battery onboard Swarm satellites complies with all controls / process requirements identified in JSC-20793 Section 5.4.3 to mitigate the chance of any accidental venting / explosion caused by the above failure modes.

Swarm satellites will include a dual mode cold gas / electric propulsion system. The non-toxic green propellant is stored in a non-pressurized propellant reservoir. There is no credible method for the propellant tank to over-pressurize (even in the case where the battery were allowed to heat the propellant without software feedback or temperature limit switches activating, it would only raise the temperature of the satellite and propellant by 85 C, from -20C to 65C (leaving a margin of safety of 4.3x of the propellant reservoir materials strength in a battery thermal runaway scenario). A micrometeorite strike could puncture the propellant reservoir, resulting in a slow release of propellant into space. Multiple barriers and tank wall thicknesses have been designed to mitigate against propellant release from micrometeorite strikes. There is no possibility of persistent droplets nor persistent solids, as the propellant exists in the gaseous phase in the vacuum of space.

Detailed Plan for any designed spacecraft breakup, including explosions and intentional collisions:

There is no planned breakup of the satellites on-orbit.

List of components passivated at EOM:

At the end of the mission, and below 300km, all radio transmissions and beacons will be disabled, and the propellant will be expelled. Spacecraft transmissions are only initiated by ground command and self terminate. All RF transmissions from the satellite can be disabled via command from the ground.

Rationale for all items required to be passivated that cannot be due to design:

N/A

Assessment of spacecraft compliance with Requirements 4.4-1 through 4.4-4:	
4.4-1, Limiting the risk to other space systems from accidental explosions during deployment and mission operations while in orbit about Earth or the Moon	COMPLIANT
4.4-2, Design for passivation after completion of mission operations while in orbit about Earth or the Moon	COMPLIANT
4.4-3, Limiting the long-term risk to other space systems from planned breakups: There are no planned breakups of any of the satellites.	COMPLIANT
4.4-4, Limiting the short-term risk to other space systems from planned breakups: There are no planned breakups of any of the satellites.	COMPLIANT

ODAR Section 5: Assessment of Spacecraft Potential for On-Orbit Collisions

Probability for Collision with Objects >10cm:

The probability of a collision of any of the Swarm satellites with an orbiting object larger than 10 cm in diameter was calculated using DAS 3.0 software. Table 1 below displays the risk of collision for satellites deployed into a range of orbital inclinations. This table was generated at the upper bound of 585 km in altitude, and with the DAS analysis period set to maximize orbital lifetime within the 2020 to 2035 timespan. These steps ensure that the individual collision risk estimates represent a bounding maximum.

In every scenario evaluated, the lifetime collision risk for any individual satellite was less than $4e-7$. Notably, this analysis now uses DAS 3.0, which has improved capability for reporting small probabilities. Swarm's previous VHF application used DAS 2.1.1, which truncated probabilities below $5e-7$ to 0.000000.

Table 1 - Collision Risk for Swarm Satellite in Each Planned Orbit in the Maximum-Lifetime Scenario

Altitude [km]	Inclination [°]	Satellite Mass [kg]	Area to mass ratio [m²/kg]	Lifetime [yrs]	Collision risk per DAS analysis
585	10	0.600	0.0262	7.8	2.09e-7
585	45	0.600	0.0262	7.9	2.43e-7
585	97.7 (SSO)	0.600	0.0262	7.8	3.99e-7

The aggregate probability of collision for the constellation was also evaluated. For aggregate probability of collision risk, the use of average satellite lifetime is preferred for bounding analysis, as the longest-lifetime estimate will underestimate the total number of satellites required to maintain the network over the grant period. Accordingly, the average anticipated lifetime of the satellites (5.0 years) is used for this analysis.

As indicated in Table 2, Swarm anticipates deploying approximately 450 satellites over the 15-year term to maintain a constellation of 150 operational satellites. Multiplying the total satellite numbers with the 5.0-year collision risk value from Table 2 yields a constellation lifetime aggregate probability of collision of 0.000065. Swarm considers 0.000065 as the most realistic probability of collision risk for the proposed constellation. In a more conservative approach (worst-case scenario), multiplying the expected satellite count by the worst-case (maximum-lifetime) individual collision risk values from Table 1 yields an aggregate probability of 0.00017. Both the realistic and worst-case methods yield total risk values substantially lower than the maximum value of 0.001 set forth in NASA Requirement 4.5-1. This analysis also conservatively assumes that the onboard propulsion is not used for collision avoidance. During operations, Swarm will coordinate with other satellite operators, and plans to employ the onboard propulsion and attitude control system to maneuver away from potential collisions. Maneuvering decisions will be based on data provided in conjunction data messages generated by both CSpOC and LeoLabs. Maneuvering plans will be provided to other satellite operators upon request.

Table 2 - Anticipated Satellite Deployments Over 15-Year License Term

# Satellites in Operational Constellation	Altitude [km]	Inclination [°]	Lifetime [yrs]	5-year Individual Collision Risk	Number of satellites deployed in given orbit over 15-year term
12	585	10	5.0	8.60e-8	36
12	585	45	5.0	1.08e-7	36
126	585	97-98 (SSO)	5.0	1.54e-7	378
				Total	450

Probability of Damage from Small Objects

Compliance with Requirement 4.5-2 requires an assessment of the probability that post-mission disposal will be impeded by damage from space objects, including small orbital debris and meteoroids, of sufficient size to prevent post-mission disposal. Because post-mission disposal in this ODAR analysis is assumed to be accomplished passively via atmospheric drag, none of the satellite subsystems are critical to completing timely post-mission disposal. The satellites therefore comply with Requirement 4.5-2. However, Swarm will employ its onboard propulsion system to avoid potential collisions and collision warnings as provided by CSpOC and LeoLabs, further reducing the aggregate probability of collision for the proposed constellation of 150 satellites.

Assessment of spacecraft compliance with Requirement 4.5-1 and 4.5-2:	
4.5-1, Probability of Collision with Large Objects:	COMPLIANT
4.5-2, Probability of Damage from Small Objects:	COMPLIANT

A DAS 3.0 log demonstrating the compliance to the above requirements is available in Appendix A – “DAS 3.0 Log”.

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

Description of Disposal Option Selected:

The satellites will be deployed from the P-POD with a spring and will separate from one another with separation springs in the feet. Following their deployment, the satellites' orbits will naturally decay until they reenter the atmosphere. Table 3 describes the mission scenarios for which lifetime analysis of Swarm satellites was considered, and the effective area-to-mass ratio of the satellite in each scenario. To determine the effective area-to-mass ratio in the nominal configuration, two years of orbital altitude history for SPACEBEE-1, 2, 3, and 4 (¼U, VHF-band Swarm satellites in LEO) were collected from Space Surveillance Network radar observations. The DAS apogee/perigee history tool was used to fit an area-to-mass ratio to those observations, using accurate solar activity data for this time period. The area-to-mass ratios were adjusted to account for the mass and configuration of the UHF satellites relative to the configuration of SPACEBEE-1, 2, 3, and 4.

Table 3 - Area-to-Mass Ratio of Swarm Satellites in Various Mission Scenarios

Scenario	Description	Effective Area-to-Mass (m ² /kg)
Nominal	<ul style="list-style-type: none"> <li>Determined empirically from observational history of previous Swarm ¼U satellites 	<p>0.0262 (for maximum satellite mass of 0.600 kg)</p>

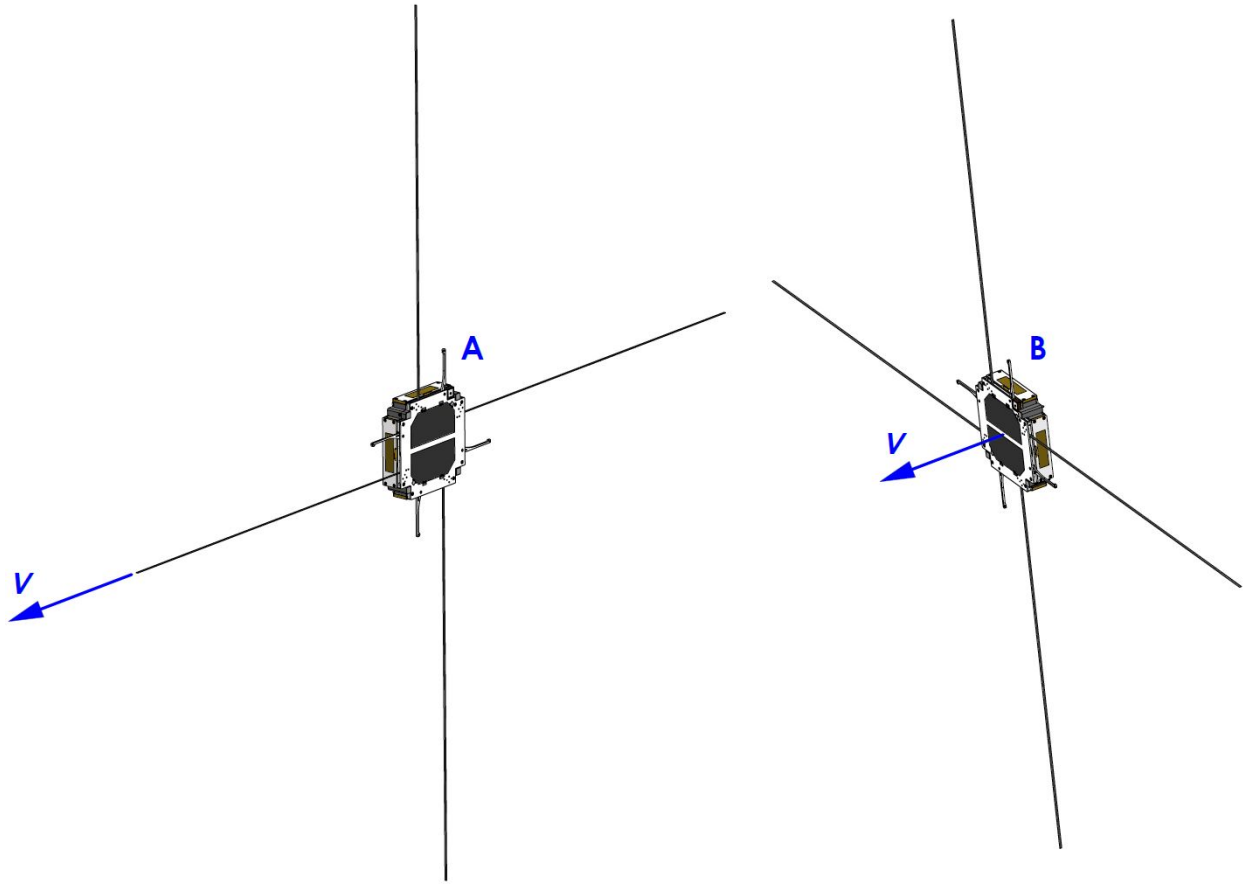


Figure 1. (A) A Swarm satellite in an edge-on flight configuration, which can be actively maintained over short intervals for space debris avoidance via differential drag. Space debris avoidance is also possible using the onboard propulsion system. A Swarm satellite has more than enough total impulse to avoid all collision warnings over the satellite lifetime.

Table 1 identifies the simulated orbital dwell time for a Swarm satellite in a range of possible orbits. In all scenarios, the dwell time of the satellite was simulated using DAS 3.0 software to be 8 years or less.

Identification of Systems Required for Post-mission Disposal: None. Although Swarm plans to employ an on-board propulsion system to aid in post-mission disposal, functional operation of this system is not required for the satellites to meet disposal requirements.

Plan for Spacecraft Maneuvers required for Post-mission Disposal: N/A

Calculation of final Area-to-Mass Ratio if Atmospheric Reentry Not Selected: N/A

Assessment of Spacecraft Compliance with Requirements 4.6-1 through 4.6-4:	
4.6-1, Disposal for space structures passing through LEO All of the satellites will reenter the atmosphere within 25 years of mission completion and 30 years of launch.	COMPLIANT

4.6-2, Disposal for space structures passing through GEO:	N/A
4.6-3, Disposal for space structures between LEO and GEO:	N/A
4.6-4, Reliability of post-mission disposal operations:	COMPLIANT

ODAR Section 7: Assessment of Spacecraft Reentry Hazards

Detailed description of spacecraft components by size, mass, material, shape, and original location on the space vehicle:

A system-level mass breakdown and primary materials list included in the generic satellite bus is available in the table below:

Table 6 - Subsystem Components Evaluated as Reentry Hazards

Subsystem	Materials	Quantity	Mass (grams)	Shape	Size (mm)
Solar Panels	Copper, Glass	2	1	Box	79 x 50 x 0.3
Main Board PCB	FR4	2	28	Box	98 x 98 x 1.6
Primary Structure	Al 6061	1	493	Box	118 x 118 x 28
Battery	Li-Ion	1	49	Cylinder	18 (r) x 67 (l)

Summary of objects expected to survive an uncontrolled reentry (using DAS 3.0 software): None
Calculation of probability of human casualty for expected reentry year and inclination: 0%

Assessment of spacecraft compliance with Requirement 4.7-1:	
4.7-1, Casualty Risk from Reentry Debris:	COMPLIANT

A DAS 3.0 log demonstrating the compliance to Requirement 4.7-1 is available in Appendix A – “DAS 3.0 Log”.

ODAR Section 7A: Assessment of Spacecraft Hazardous Materials

Summary of Hazardous Materials Contained on Spacecraft: None

ODAR Section 8: Assessment for Tether Missions

Type of tether: N/A

Description of tether system: N/A

Determination of minimum size of object that will cause the tether to be severed: N/A

Tether mission plan, including duration and post-mission disposal: N/A

Probability of tether colliding with large space objects: N/A

Probability of tether being severed during mission or after post-mission disposal: N/A

Maximum orbital lifetime of a severed tether fragment: N/A

Assessment of compliance with Requirement 4.8-1:	
4.8-1, Collision Hazards of Space Tethers:	N/A

Appendix A: DAS 3.0 Log

04 05 2020; 23:21:32PM Activity Log Started

04 05 2020; 23:42:37PM Science and Engineering - Orbit Lifetime/Dwell Time

****INPUT****

Start Year = 2024.600000 (yr)
 Perigee Altitude = 300.000000 (km)
 Apogee Altitude = 300.000000 (km)
 Inclination = 10.000000 (deg)
 RAAN = 0.000000 (deg)
 Argument of Perigee = 0.000000 (deg)
 Area-To-Mass Ratio = 0.026200 (m²/kg)

****OUTPUT****

Orbital Lifetime from Startyr = 0.021903 (yr)
 Time Spent in LEO during Lifetime = 0.021903 (yr)
 Last year of Propagation = 2024 (yr)
 Returned Error Message: Object reentered
 04 05 2020; 23:42:48PM Science and Engineering - Orbit Lifetime/Dwell Time

****INPUT****

Start Year = 2024.600000 (yr)
 Perigee Altitude = 300.000000 (km)
 Apogee Altitude = 300.000000 (km)
 Inclination = 45.000000 (deg)
 RAAN = 0.000000 (deg)

Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.026200 (m²/kg)

OUTPUT

Orbital Lifetime from Startyr = 0.027379 (yr)
Time Spent in LEO during Lifetime = 0.027379 (yr)
Last year of Propagation = 2024 (yr)
Returned Error Message: Object reentered
04 05 2020; 23:42:59PM Science and Engineering - Orbit Lifetime/Dwell Time

INPUT

Start Year = 2024.600000 (yr)
Perigee Altitude = 300.000000 (km)
Apogee Altitude = 300.000000 (km)
Inclination = 96.700000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.026200 (m²/kg)

OUTPUT

Orbital Lifetime from Startyr = 0.027379 (yr)
Time Spent in LEO during Lifetime = 0.027379 (yr)
Last year of Propagation = 2024 (yr)
Returned Error Message: Object reentered
04 05 2020; 23:43:11PM Science and Engineering - Orbit Lifetime/Dwell Time

INPUT

Start Year = 2024.600000 (yr)
Perigee Altitude = 585.000000 (km)
Apogee Altitude = 585.000000 (km)
Inclination = 10.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.026200 (m²/kg)

OUTPUT

Orbital Lifetime from Startyr = 7.802875 (yr)
Time Spent in LEO during Lifetime = 7.802875 (yr)
Last year of Propagation = 2032 (yr)
Returned Error Message: Object reentered
04 05 2020; 23:43:23PM Science and Engineering - Orbit Lifetime/Dwell Time

INPUT

Start Year = 2024.600000 (yr)
Perigee Altitude = 585.000000 (km)
Apogee Altitude = 585.000000 (km)
Inclination = 45.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.026200 (m²/kg)

****OUTPUT****

Orbital Lifetime from Startyr = 7.890486 (yr)
Time Spent in LEO during Lifetime = 7.890486 (yr)
Last year of Propagation = 2032 (yr)
Returned Error Message: Object reentered
04 05 2020; 23:43:33PM Science and Engineering - Orbit Lifetime/Dwell Time

****INPUT****

Start Year = 2024.600000 (yr)
Perigee Altitude = 585.000000 (km)
Apogee Altitude = 585.000000 (km)
Inclination = 97.700000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.026200 (m²/kg)

****OUTPUT****

Orbital Lifetime from Startyr = 7.786448 (yr)
Time Spent in LEO during Lifetime = 7.786448 (yr)
Last year of Propagation = 2032 (yr)
Returned Error Message: Object reentered
04 05 2020; 23:46:48PM Processing Requirement 4.3-1: Return Status : Not Run

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

=====
End of Requirement 4.3-1 =====
04 05 2020; 23:46:57PM Processing Requirement 4.3-2: Return Status : Passed

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

=====
End of Requirement 4.3-2 =====

04 06 2020; 00:30:56AM Processing Requirement 4.5-1: Return Status : Passed

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

****INPUT****

Space Structure Name = 300 km 10 deg
Space Structure Type = Payload
Perigee Altitude = 300.000 (km)
Apogee Altitude = 300.000 (km)
Inclination = 10.000 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0262 (m²/kg)
Start Year = 2024.600 (yr)
Initial Mass = 0.600 (kg)
Final Mass = 0.600 (kg)
Duration = 0.022 (yr)
Station-Kept = False
Abandoned = True

****OUTPUT****

Collision Probability = 6.1131E-11
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

=====
****INPUT****

Space Structure Name = 300 km 45 deg
Space Structure Type = Payload
Perigee Altitude = 300.000 (km)
Apogee Altitude = 300.000 (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 = 0.0262 (m²/kg)
Start Year = 2024.600 (yr)
Initial Mass = 0.600 (kg)
Final Mass = 0.600 (kg)
Duration = 0.027 (yr)

Station-Kept = False
Abandoned = True

OUTPUT

Collision Probability = 6.1620E-11
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

=====

INPUT

Space Structure Name = 300 km SSO
Space Structure Type = Payload
Perigee Altitude = 300.000 (km)
Apogee Altitude = 300.000 (km)
Inclination = 96.700 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0262 (m²/kg)
Start Year = 2024.600 (yr)
Initial Mass = 0.600 (kg)
Final Mass = 0.600 (kg)
Duration = 0.027 (yr)
Station-Kept = False
Abandoned = True

OUTPUT

Collision Probability = 9.0159E-11
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

=====

INPUT

Space Structure Name = 585 km 10 deg
Space Structure Type = Payload
Perigee Altitude = 585.000 (km)
Apogee Altitude = 585.000 (km)
Inclination = 10.000 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)

Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0262 (m²/kg)
Start Year = 2024.600 (yr)
Initial Mass = 0.600 (kg)
Final Mass = 0.600 (kg)
Duration = 7.803 (yr)
Station-Kept = False
Abandoned = True

****OUTPUT****

Collision Probability = 2.0873E-07
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

=====

****INPUT****

Space Structure Name = 585 km 45 deg
Space Structure Type = Payload
Perigee Altitude = 585.000 (km)
Apogee Altitude = 585.000 (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 = 0.0262 (m²/kg)
Start Year = 2024.600 (yr)
Initial Mass = 0.600 (kg)
Final Mass = 0.600 (kg)
Duration = 7.890 (yr)
Station-Kept = False
Abandoned = True

****OUTPUT****

Collision Probability = 2.4274E-07
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

=====

****INPUT****

Space Structure Name = 585 km SSO

Space Structure Type = Payload
Perigee Altitude = 585.000 (km)
Apogee Altitude = 585.000 (km)
Inclination = 97.700 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0262 (m²/kg)
Start Year = 2024.600 (yr)
Initial Mass = 0.600 (kg)
Final Mass = 0.600 (kg)
Duration = 7.786 (yr)
Station-Kept = False
Abandoned = True

****OUTPUT****

Collision Probability = 3.9873E-07
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

=====

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

04 06 2020; 00:32:29AM Processing Requirement 4.6 Return Status : Passed

=====

Project Data

=====

****INPUT****

Space Structure Name = 300 km 10 deg
Space Structure Type = Payload

Perigee Altitude = 300.000000 (km)
Apogee Altitude = 300.000000 (km)
Inclination = 10.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.026200 (m²/kg)
Start Year = 2024.600000 (yr)
Initial Mass = 0.600000 (kg)
Final Mass = 0.600000 (kg)
Duration = 0.022000 (yr)

Station Kept = False
Abandoned = True
PMD Perigee Altitude = 192.404755 (km)
PMD Apogee Altitude = 194.843675 (km)
PMD Inclination = 9.996869 (deg)
PMD RAAN = 291.325280 (deg)
PMD Argument of Perigee = 55.602466 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 192.404755 (km)
Suggested Apogee Altitude = 194.843675 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

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

=====

INPUT

Space Structure Name = 300 km 45 deg
Space Structure Type = Payload

Perigee Altitude = 300.000000 (km)
Apogee Altitude = 300.000000 (km)
Inclination = 45.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.026200 (m²/kg)
Start Year = 2024.600000 (yr)
Initial Mass = 0.600000 (kg)
Final Mass = 0.600000 (kg)
Duration = 0.027000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 145.076347 (km)
PMD Apogee Altitude = 147.453542 (km)
PMD Inclination = 44.983465 (deg)
PMD RAAN = 299.638461 (deg)
PMD Argument of Perigee = 17.731954 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 145.076347 (km)
Suggested Apogee Altitude = 147.453542 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

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

=====

INPUT

Space Structure Name = 300 km SSO
Space Structure Type = Payload

Perigee Altitude = 300.000000 (km)
Apogee Altitude = 300.000000 (km)
Inclination = 96.700000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.026200 (m²/kg)
Start Year = 2024.600000 (yr)
Initial Mass = 0.600000 (kg)
Final Mass = 0.600000 (kg)
Duration = 0.027000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 144.726909 (km)
PMD Apogee Altitude = 146.802098 (km)
PMD Inclination = 96.677241 (deg)
PMD RAAN = 9.889855 (deg)
PMD Argument of Perigee = 181.961595 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 144.726909 (km)
Suggested Apogee Altitude = 146.802098 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

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

=====

INPUT

Space Structure Name = 585 km 10 deg
Space Structure Type = Payload

Perigee Altitude = 585.000000 (km)
Apogee Altitude = 585.000000 (km)
Inclination = 10.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.026200 (m²/kg)
Start Year = 2024.600000 (yr)
Initial Mass = 0.600000 (kg)
Final Mass = 0.600000 (kg)
Duration = 7.803000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 206.690504 (km)
PMD Apogee Altitude = 207.916657 (km)
PMD Inclination = 9.992190 (deg)
PMD RAAN = 316.764110 (deg)
PMD Argument of Perigee = 80.945211 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 206.690504 (km)
Suggested Apogee Altitude = 207.916657 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2032 (yr)
Requirement = 61
Compliance Status = Pass

=====

INPUT

Space Structure Name = 585 km 45 deg
Space Structure Type = Payload

Perigee Altitude = 585.000000 (km)
Apogee Altitude = 585.000000 (km)
Inclination = 45.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.026200 (m²/kg)

Start Year = 2024.600000 (yr)
Initial Mass = 0.600000 (kg)
Final Mass = 0.600000 (kg)
Duration = 7.890000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 184.116993 (km)
PMD Apogee Altitude = 188.218796 (km)
PMD Inclination = 44.957078 (deg)
PMD RAAN = 122.379290 (deg)
PMD Argument of Perigee = 61.868869 (deg)
PMD Mean Anomaly = 0.000000 (deg)

****OUTPUT****

Suggested Perigee Altitude = 184.116993 (km)
Suggested Apogee Altitude = 188.218796 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2032 (yr)
Requirement = 61
Compliance Status = Pass

=====

****INPUT****

Space Structure Name = 585 km SSO
Space Structure Type = Payload

Perigee Altitude = 585.000000 (km)
Apogee Altitude = 585.000000 (km)
Inclination = 97.700000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.026200 (m²/kg)
Start Year = 2024.600000 (yr)
Initial Mass = 0.600000 (kg)
Final Mass = 0.600000 (kg)
Duration = 7.786000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 165.243079 (km)
PMD Apogee Altitude = 168.409628 (km)
PMD Inclination = 97.755744 (deg)
PMD RAAN = 16.922245 (deg)
PMD Argument of Perigee = 108.225458 (deg)

PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 165.243079 (km)
Suggested Apogee Altitude = 168.409628 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2032 (yr)
Requirement = 61
Compliance Status = Pass

=====

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

04 06 2020; 01:30:38AM Processing Requirement 4.6 Return Status : Passed

=====

Project Data

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INPUT

Space Structure Name = 300 km 10 deg
Space Structure Type = Payload

Perigee Altitude = 300.000000 (km)
Apogee Altitude = 300.000000 (km)
Inclination = 10.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.026200 (m²/kg)
Start Year = 2024.600000 (yr)
Initial Mass = 0.600000 (kg)
Final Mass = 0.600000 (kg)
Duration = 0.022000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 192.404755 (km)
PMD Apogee Altitude = 194.843675 (km)
PMD Inclination = 9.996869 (deg)
PMD RAAN = 291.325280 (deg)
PMD Argument of Perigee = 55.602466 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 192.404755 (km)
Suggested Apogee Altitude = 194.843675 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

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

=====

INPUT

Space Structure Name = 300 km 45 deg
Space Structure Type = Payload

Perigee Altitude = 300.000000 (km)
Apogee Altitude = 300.000000 (km)
Inclination = 45.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.026200 (m²/kg)
Start Year = 2024.600000 (yr)
Initial Mass = 0.600000 (kg)
Final Mass = 0.600000 (kg)
Duration = 0.027000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 145.076347 (km)
PMD Apogee Altitude = 147.453542 (km)
PMD Inclination = 44.983465 (deg)
PMD RAAN = 299.638461 (deg)
PMD Argument of Perigee = 17.731954 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 145.076347 (km)
Suggested Apogee Altitude = 147.453542 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

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

=====

INPUT

Space Structure Name = 300 km SSO
Space Structure Type = Payload

Perigee Altitude = 300.000000 (km)
Apogee Altitude = 300.000000 (km)
Inclination = 96.700000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.026200 (m²/kg)
Start Year = 2024.600000 (yr)
Initial Mass = 0.600000 (kg)
Final Mass = 0.600000 (kg)
Duration = 0.027000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 144.726909 (km)
PMD Apogee Altitude = 146.802098 (km)
PMD Inclination = 96.677241 (deg)
PMD RAAN = 9.889855 (deg)
PMD Argument of Perigee = 181.961595 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 144.726909 (km)
Suggested Apogee Altitude = 146.802098 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

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

=====

INPUT

Space Structure Name = 585 km 10 deg
Space Structure Type = Payload

Perigee Altitude = 585.000000 (km)
Apogee Altitude = 585.000000 (km)
Inclination = 10.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.026200 (m²/kg)

Start Year = 2024.600000 (yr)
Initial Mass = 0.600000 (kg)
Final Mass = 0.600000 (kg)
Duration = 7.803000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 206.690504 (km)
PMD Apogee Altitude = 207.916657 (km)
PMD Inclination = 9.992190 (deg)
PMD RAAN = 316.764110 (deg)
PMD Argument of Perigee = 80.945211 (deg)
PMD Mean Anomaly = 0.000000 (deg)

****OUTPUT****

Suggested Perigee Altitude = 206.690504 (km)
Suggested Apogee Altitude = 207.916657 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2032 (yr)
Requirement = 61
Compliance Status = Pass

=====

****INPUT****

Space Structure Name = 585 km 45 deg
Space Structure Type = Payload

Perigee Altitude = 585.000000 (km)
Apogee Altitude = 585.000000 (km)
Inclination = 45.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.026200 (m²/kg)
Start Year = 2024.600000 (yr)
Initial Mass = 0.600000 (kg)
Final Mass = 0.600000 (kg)
Duration = 7.890000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 184.116993 (km)
PMD Apogee Altitude = 188.218796 (km)
PMD Inclination = 44.957078 (deg)
PMD RAAN = 122.379290 (deg)
PMD Argument of Perigee = 61.868869 (deg)

PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 184.116993 (km)
Suggested Apogee Altitude = 188.218796 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2032 (yr)
Requirement = 61
Compliance Status = Pass

=====

INPUT

Space Structure Name = 585 km SSO
Space Structure Type = Payload

Perigee Altitude = 585.000000 (km)
Apogee Altitude = 585.000000 (km)
Inclination = 97.700000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.026200 (m²/kg)
Start Year = 2024.600000 (yr)
Initial Mass = 0.600000 (kg)
Final Mass = 0.600000 (kg)
Duration = 7.786000 (yr)
Station Kept = False
Abandoned = True

PMD Perigee Altitude = 165.243079 (km)
PMD Apogee Altitude = 168.409628 (km)
PMD Inclination = 97.755744 (deg)
PMD RAAN = 16.922245 (deg)
PMD Argument of Perigee = 108.225458 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 165.243079 (km)
Suggested Apogee Altitude = 168.409628 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2032 (yr)
Requirement = 61
Compliance Status = Pass

=====

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

04 06 2020; 01:30:38AM *****Processing Requirement 4.7-1

Return Status : Passed

*****INPUT****

Item Number = 1

name = 300 km 10 deg
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 0.600000
Thermal Mass = 0.600000
Diameter/Width = 0.118000
Length = 0.118000
Height = 0.028000

name = Solar Panels
quantity = 2
parent = 1
materialID = 24
type = Box
Aero Mass = 0.001000
Thermal Mass = 0.001000
Diameter/Width = 0.050000
Length = 0.079000
Height = 0.000300

name = Main Board PCB
quantity = 2
parent = 1
materialID = 23
type = Box
Aero Mass = 0.028000
Thermal Mass = 0.028000
Diameter/Width = 0.118000
Length = 0.118000
Height = 0.001600

name = Battery
quantity = 1
parent = 1
materialID = 5
type = Cylinder

Aero Mass = 0.049000
Thermal Mass = 0.049000
Diameter/Width = 0.039000
Length = 0.067000

name = Primary Structure
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.493000
Thermal Mass = 0.493000
Diameter/Width = 0.118000
Length = 0.118000
Height = 0.028000

*****OUTPUT*****

Item Number = 1

name = 300 km 10 deg
Demise Altitude = 77.993393
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = Solar Panels
Demise Altitude = 77.974236
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = Main Board PCB
Demise Altitude = 77.350868
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = Battery
Demise Altitude = 74.734848
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = Primary Structure
Demise Altitude = 66.125908
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*****INPUT****

Item Number = 2

name = 300 km 45 deg
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 0.600000
Thermal Mass = 0.600000
Diameter/Width = 0.118000
Length = 0.118000
Height = 0.028000

name = 3
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.600000
Thermal Mass = 0.600000
Diameter/Width = 0.118000
Length = 0.118000
Height = 0.028000

*****OUTPUT****

Item Number = 2

name = 300 km 45 deg
Demise Altitude = 77.998398
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = 3
Demise Altitude = 64.741219
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*****INPUT****

Item Number = 3

name = 300 km SSO
quantity = 1

parent = 0
materialID = 5
type = Box
Aero Mass = 0.600000
Thermal Mass = 0.600000
Diameter/Width = 0.118000
Length = 0.118000
Height = 0.028000

name = 3
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.600000
Thermal Mass = 0.600000
Diameter/Width = 0.118000
Length = 0.118000
Height = 0.028000

*****OUTPUT****

Item Number = 3

name = 300 km SSO
Demise Altitude = 77.994133
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = 3
Demise Altitude = 66.722610
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*****INPUT****

Item Number = 4

name = 585 km 10 deg
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 0.600000
Thermal Mass = 0.600000
Diameter/Width = 0.118000
Length = 0.118000

Height = 0.028000

name = 5
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.600000
Thermal Mass = 0.600000
Diameter/Width = 0.118000
Length = 0.118000
Height = 0.028000

*****OUTPUT*****

Item Number = 4

name = 585 km 10 deg
Demise Altitude = 77.993393
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = 5
Demise Altitude = 63.973984
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*****INPUT*****

Item Number = 5

name = 585 km 45 deg
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 0.600000
Thermal Mass = 0.600000
Diameter/Width = 0.118000
Length = 0.118000
Height = 0.028000

name = 5
quantity = 1
parent = 1
materialID = 5
type = Box

Aero Mass = 0.600000
Thermal Mass = 0.600000
Diameter/Width = 0.118000
Length = 0.118000
Height = 0.028000

*****OUTPUT****

Item Number = 5

name = 585 km 45 deg
Demise Altitude = 77.998398
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = 5
Demise Altitude = 64.741219
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*****INPUT****

Item Number = 6

name = 585 km SSO
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 0.600000
Thermal Mass = 0.600000
Diameter/Width = 0.118000
Length = 0.118000
Height = 0.028000

name = 5
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.600000
Thermal Mass = 0.600000
Diameter/Width = 0.118000
Length = 0.118000
Height = 0.028000

*****OUTPUT****

Item Number = 6

name = 585 km SSO
Demise Altitude = 77.992897
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = 5
Demise Altitude = 66.759682
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

=====
===== End of Requirement 4.7-1 =====
04 06 2020; 01:30:38AM Project Data Saved To File