

LEMUR-2 Orbital Debris Assessment Report

NANOSATISFI MARKET MISSION PROFILE

PREPARED BY: SPIRE GLOBAL INC

REVISION 3

2015

Revision History

Revision	Description of Revisions	Release Date
1	(baseline version)	02/10/2015
2	Updated launch information based on new info from launch providers: <ul style="list-style-type: none">• PSLV expected launch date moved from Q3 2015 to Q4 2015 Added newly-booked launches: <ul style="list-style-type: none">• “TBD” launch updated to “Q4 2015 Atlas-V / Cyngnus” launch• added Q1 2016 Soyuz launch• updated quantity of satellites on Q1 2016 Falcon-9 launch to 10 New DAS log with updated launch information.	04/22/2015
3	Updated orbital decay information by including tensile strength decay of filaments	05/23/2015

Summarized List of Compliance Status to Orbital Debris Requirements

For convenience, below is a summarized list of the compliance status to orbital debris requirements. Detailed explanations for each of these compliance statements are available in ODAR Sections 1 through 8.

4.3-1, Mission-Related Debris Passing Through LEO:	COMPLIANT
4.3-2, Mission-Related Debris Passing Near GEO	COMPLIANT
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:	N/A
4.4-3, Limiting the long-term risk to other space systems from planned breakups:	COMPLIANT
4.4-4, Limiting the short-term risk to other space systems from planned breakups:	COMPLIANT
4.5-1, Probability of Collision with Large Objects:	COMPLIANT
4.5-2, Probability of Damage from Small Objects:	COMPLIANT
4.6-1, Disposal for space structures passing through LEO:	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 postmission disposal operations:	N/A
4.8-1, Collision Hazards of Space Tethers	N/A

ODAR Section 1: Program Management and Mission Overview

Program / Project Manager	Peter Platzer																																																							
Mission Description	The purpose of the LEMUR-2 nanosatellite fleet is to provide high-revisit maritime domain monitoring data, as part of a market trial to test marked demand in this area. The mission consists of a set of 17 3U Cubesats satellites launched in four separate launch vehicles launches into various orbital planes, to increase average revisit time globally. The LEMUR-2 fleet is a continuation of the market trial currently underway with the single prototype LEMUR-1 satellite.																																																							
Foreign Government Involvement	None																																																							
Project Milestones:	The project milestones for the LEMUR-2 constellations align with the successive launch of vehicles into orbit. The table blow contains launch segment information for each launch of the constellation.																																																							
Proposed Launch Date:																																																								
Proposed Launch Vehicles:	<table border="1"> <thead> <tr> <th>Vehicle</th> <th>Proposed Launch Date (no earlier than)</th> <th>Number of Satellites</th> <th>Launch Vehicle Operator</th> <th>Launch Site</th> <th>Altitude</th> <th>Inclination</th> </tr> </thead> <tbody> <tr> <td>PSLV</td> <td>Q4 2015</td> <td>4</td> <td>Antrix / ISRO</td> <td>Sriharikota, India</td> <td>650 km</td> <td>6 deg</td> </tr> <tr> <td>Atlas V</td> <td>Q4 2015</td> <td>4</td> <td>Orbital Sciences</td> <td>Cape Canaveral, FL</td> <td>500 km</td> <td>51.6 deg</td> </tr> <tr> <td>Soyuz</td> <td>Q4 2015</td> <td>2</td> <td>Roscosmos</td> <td>Baikonur, Kazakhstan</td> <td>600 km</td> <td>98 deg</td> </tr> <tr> <td>HII-A</td> <td>January 2016</td> <td>7</td> <td>JAMSS / JAXA</td> <td>Tanegashima, Japan</td> <td>575 km</td> <td>31 deg</td> </tr> <tr> <td>Falcon-9</td> <td>Q1 2016</td> <td>10</td> <td>Space-X</td> <td>Vandenberg, CA, US</td> <td>450 x 720 km</td> <td>98 deg</td> </tr> <tr> <td>Soyuz</td> <td>Q1 2016</td> <td>4</td> <td>Roscosmos</td> <td>Baikonur, Kazakhstan</td> <td>600 km</td> <td>98 deg</td> </tr> </tbody> </table>							Vehicle	Proposed Launch Date (no earlier than)	Number of Satellites	Launch Vehicle Operator	Launch Site	Altitude	Inclination	PSLV	Q4 2015	4	Antrix / ISRO	Sriharikota, India	650 km	6 deg	Atlas V	Q4 2015	4	Orbital Sciences	Cape Canaveral, FL	500 km	51.6 deg	Soyuz	Q4 2015	2	Roscosmos	Baikonur, Kazakhstan	600 km	98 deg	HII-A	January 2016	7	JAMSS / JAXA	Tanegashima, Japan	575 km	31 deg	Falcon-9	Q1 2016	10	Space-X	Vandenberg, CA, US	450 x 720 km	98 deg	Soyuz	Q1 2016	4	Roscosmos	Baikonur, Kazakhstan	600 km	98 deg
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Mission Duration:	The operational lifetime of each satellite is estimated to be up to 2 years following deployment from the launch vehicle. The orbital lifetime for the constellation is nominally expected to be between 5-8 years, depending on the vehicle's orbit, as described in Section 6.																																																							

<p>Launch / Deployment Profile:</p>	<p>Launch LEMUR-2 satellites will be injected directly into the target orbits outlined in the table above.</p> <p>Checkout For up to 1 month following deployment into orbit, LEMUR-2 satellites will remain in checkout phase. During this phase, ground operators will verify correct operation of the satellite and its payloads, and prepare it for the operational phase.</p> <p>Operations The operational phase of the satellite begins following the successful deployment of the satellite from the launch vehicle, and successful checkout. The operational phase continues until the end of the market study.</p> <p>Postmission Disposal Following the end of the operational phase, the satellites will remain on orbit in a non-transmitting mode while the orbit of the satellite passively decays until the satellite reenters the atmosphere and disintegrates. The satellite is nominally expected to reenter the atmosphere 10 years following deployment from the launch vehicle, as detailed in Appendix B: LEMUR1 Orbit Lifetime</p>
<p>Selection of Orbit:</p>	<p>The selection of the chosen orbit was made due to available launch opportunities.</p>
<p>Potential Physical Interference with Other Orbiting Object:</p>	<p>As the satellite does not have any propulsion systems, its orbit 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 satellite complies with Requirement 4.5.</p>

ODAR Section 2: Spacecraft Description

Physical Description:

Property	Value
Total Mass at Launch	4.5kg
Dry Mass at Launch	4.5kg
Form Factor	3U CubeSat
COG	<3cm radius from geometric center
Envelope (stowed)	100mm x 100mm x 340.5mm (excluding dynamic envelope)
Envelope (deployed)	1m x 1m x 300mm
Propulsion Systems	None
Fluid Systems	None
AOCS	Stabilization/pointing with 3x orthogonal reaction wheels, desaturation + coarse pointing with magnetorquers, GPS navigation
Range Safety / Pyrotechnic Devices	None
Electrical Generation	Triple-junction GaAs solar panels
Electrical Storage	Rechargeable lithium-polymer battery pack
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
4.3-2, Mission-Related Debris Passing Near GEO:	COMPLIANT

A DAS 2.0.2 log demonstrating the compliance to the above requirements is available in Appendix A – “DAS 2.0.2 Log”.

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

Potential causes for spacecraft breakup:

There are only two plausible causes for breakup of the satellites:

- energy released from onboard batteries, and
- mechanical failure of the reaction wheels

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

The batteries aboard the satellites are two 42Wh Lithium-Polymer batteries, and represent the only credible failure mode during which stored energy is released. The main failure modes associated with Lithium Polymer batteries result from overcharging, overdischarging, internal shorts, and external shorts.

The battery pack onboard LEMUR-2 satellites complies with all controls / process requirements identified in JSC-20793 Section 5.4.3 to mitigate chance of any accidental venting / explosion caused by the above failure modes.

The only failure mode of the reaction wheel assemblies that could lead to creation of debris would be breakup of the wheels themselves due to mechanical failure while operating at a high angular rate. Risk mitigation strategies for breakups due to the reaction wheels include limiting the maximum rotational speed of the wheels, and containing them within a sealed compartment.

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

There is no planned breakup the satellites on-orbit.

List of components passivated at EOM:

At the end of mission, the only components that will require passivation are the reaction wheels. At the end of the mission, the reaction wheels will be de-spun to passivate.

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 satellites with an orbiting object larger than 10cm in diameter was sufficiently small that the simulation performed using DAS 2.0.2 software returned a probability value of 0.

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 2.0.2 log demonstrating the compliance to the above requirements is available in Appendix A – “DAS 2.0.2 Log”.

ODAR Section 6: Assessment of Spacecraft Postmission Disposal Plans and Procedures

Description of Disposal Option Selected:

Following its deployment, the satellite's orbit will naturally decay until it reenters the atmosphere. Table 1 describes the mission scenarios for which lifetime analysis of LEMUR-2 was considered, and the effective area-to-mass ratio of the satellite in each scenario. The ratio was calculated using the external dimensions of the satellite and deployed arrays.

Drag area from deployed antennas (2x 0.5m whip antennas, 3x 0.3m whip antennas) was neglected; as such, the effective area-to-mass calculated below is a conservative case.

Table 1 - Area-to-Mass Ratio of LEMUR-2 Satellites in Various Mission Scenarios

Scenario	Description	Effective Area-to-Mass (m ² /kg)
Satellite Nonfunctional	<ul style="list-style-type: none"> ▪ Solar arrays deploy only after 5 years ▪ Satellite tumbles randomly 	0.0000 (yrs 1-5) ¹ 0.0169 (yrs 5+)
Solar panel failure	<ul style="list-style-type: none"> ▪ Solar panels fail to deploy ▪ Satellite maintains +Z axis nadir ▪ Position around Z axis as planned for mission operations 	0.0130
Operational, nominal	<ul style="list-style-type: none"> ▪ Solar panels deploy ▪ Satellite maintains +Z axis nadir ▪ Position around Z axis as planned for mission operations 	0.0208
ADCS Nonfunctional	<ul style="list-style-type: none"> ▪ Solar arrays deploy ▪ Satellite tumbles randomly 	0.0169

¹ For the analysis, it was conservatively assumed that the satellite does not lose any altitude during the first 5 years (ie, an area of 0).

Table 2 shows the simulated orbital dwell time for a LEMUR-2 satellite in each of the planned orbits of the constellation, in each of the identified mission scenarios. In all mission scenarios and orbits, the dwell time of the satellite was simulated using DAS 2.0.2 software to be less than 20 years.

Table 2 – Orbit Dwell Time for LEMUR-2 Satellite in Each Planned Orbit and Mission Scenario

Description	Effective Area-to-Mass (m ² /kg)	Orbital Lifetime (Years)					
		Q4 2015 Soyuz (2 satellites)	Q1 2016 HII-A (7 satellites)	Q1 2016 Falcon-9 (10 satellites)	Q4 2015 PSLV (4 satellites)	Q4 2015 Atlas V (4 satellites)	Q1 2016 Soyuz (4 satellites)
		600km x 600km SSO	575km x 575km, 31 deg	750km x 450km, SSO	650km x 650km, 6 deg	500km x 500km, 51.6 deg	600km x 600km SSO
Satellite Nonfunctional	0.0074	19.8	17.0	11.6	23.8²	7.2	19.8
Solar panels failure	0.0130	11.1	8.8	8.0	23.2	6.1	11.1
ADCS Nonfunctional	0.0169	9.0	8.0	7.4	18.8	5.7	9.0
Operational, Nominal	0.0208	8.3	7.5	6.9	17.3	5.2	8.3

Identification of Systems Required for Postmission Disposal: None

Plan for Spacecraft Maneuvers required for Postmission 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 postmission disposal operations:	COMPLIANT

² No decay in first 5 years, after that deployment of antenna and solar panel due to decay of nylon filament with an effective area/mass of 0.0169 m²/kg

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:

Subsystem	Materials	Quantity	Mass (g)	Shape	Size (mm)
Solar Panels (long)	Glass, GaAs, FR4 PCB	6	150	Flat Plate	100 x 300
GPS Antenna (large)	Aluminum	1	450	Box	300 x 80 x 8
GPS Antenna (small)	Aluminum	1	50	Box	50 x 50 x 17
Subsystem PCBs	FR4 PCB	12	80	Flat Plate	90 x 90
Primary Structure	Aluminum	1	560	Box	100 x 100 x 300
Optical Camera	Aluminum, FR4 PCB, Glass	1	350	Cylinder	30 x 100
Reaction wheel assembly + enclosure	Aluminum, copper, FR4 PCB	1	600	Box	100 x 100 x 56
Battery pack	Li-Polymer	2	470	Box	80 x 60 x 40

Summary of objects expected to survive an uncontrolled reentry (using DAS 2.0.2 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 2.0.2 log demonstrating the compliance to Requirement 4.7-1 is available in Appendix A – “DAS 2.0.2 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 postmission disposal: N/A

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

Probability of tether being severed during mission or after postmission 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 2.0.2 Log

Below is the log of the DAS 2.0.2 simulation performed to demonstrate compliance to the above requirements.

```
04 22 2015; 22:49:55PM    DAS Application Started
04 22 2015; 22:49:57PM    Opened Project C:\Program Files (x86)\NASA\DAS
2.0\project\
04 22 2015; 22:50:57PM    Opened Project
C:\Users\nanosatisfi\Downloads\ODAR-2015-04-22\ODAR\
04 22 2015; 22:51:47PM    Science and Engineering - Orbit Lifetime/Dwell
Time
```

INPUT

```
Start Year = 2015.500000 (yr)
Perigee Altitude = 500.000000 (km)
Apogee Altitude = 500.000000 (km)
Inclination = 51.600000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.007400 (m^2/kg)
```

OUTPUT

```
Orbital Lifetime from Startyr = 7.178645 (yr)
Time Spent in LEO during Lifetime = 7.178645 (yr)
Last year of Propagation = 2022 (yr)
Returned Error Message: Object reentered
04 22 2015; 22:52:41PM    Science and Engineering - Orbit Lifetime/Dwell
Time
```

INPUT

```
Start Year = 2015.500000 (yr)
Perigee Altitude = 500.000000 (km)
Apogee Altitude = 500.000000 (km)
Inclination = 51.600000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.013000 (m^2/kg)
```

OUTPUT

```
Orbital Lifetime from Startyr = 6.121834 (yr)
Time Spent in LEO during Lifetime = 6.121834 (yr)
Last year of Propagation = 2021 (yr)
```

Returned Error Message: Object reentered
04 22 2015; 22:52:51PM Science and Engineering - Orbit Lifetime/Dwell
Time

INPUT

Start Year = 2015.500000 (yr)
Perigee Altitude = 500.000000 (km)
Apogee Altitude = 500.000000 (km)
Inclination = 51.600000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.016900 (m²/kg)

OUTPUT

Orbital Lifetime from Startyr = 5.700205 (yr)
Time Spent in LEO during Lifetime = 5.700205 (yr)
Last year of Propagation = 2021 (yr)
Returned Error Message: Object reentered
04 22 2015; 22:53:02PM Science and Engineering - Orbit Lifetime/Dwell
Time

INPUT

Start Year = 2015.500000 (yr)
Perigee Altitude = 500.000000 (km)
Apogee Altitude = 500.000000 (km)
Inclination = 51.600000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.020800 (m²/kg)

OUTPUT

Orbital Lifetime from Startyr = 5.212868 (yr)
Time Spent in LEO during Lifetime = 5.212868 (yr)
Last year of Propagation = 2020 (yr)
Returned Error Message: Object reentered
04 22 2015; 22:53:24PM Science and Engineering - Orbit Lifetime/Dwell
Time

INPUT

Start Year = 2015.500000 (yr)
Perigee Altitude = 600.000000 (km)
Apogee Altitude = 600.000000 (km)
Inclination = 98.000000 (deg)

RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.020800 (m²/kg)

OUTPUT

Orbital Lifetime from Startyr = 8.268309 (yr)
Time Spent in LEO during Lifetime = 8.268309 (yr)
Last year of Propagation = 2023 (yr)
Returned Error Message: Object reentered

04 22 2015; 22:53:38PM Science and Engineering - Orbit Lifetime/Dwell
Time

INPUT

Start Year = 2015.500000 (yr)
Perigee Altitude = 600.000000 (km)
Apogee Altitude = 600.000000 (km)
Inclination = 98.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.016900 (m²/kg)

OUTPUT

Orbital Lifetime from Startyr = 8.974675 (yr)
Time Spent in LEO during Lifetime = 8.974675 (yr)
Last year of Propagation = 2024 (yr)
Returned Error Message: Object reentered

04 22 2015; 22:53:46PM Science and Engineering - Orbit Lifetime/Dwell
Time

INPUT

Start Year = 2015.500000 (yr)
Perigee Altitude = 600.000000 (km)
Apogee Altitude = 600.000000 (km)
Inclination = 98.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.013000 (m²/kg)

OUTPUT

Orbital Lifetime from Startyr = 11.082820 (yr)
Time Spent in LEO during Lifetime = 11.082820 (yr)
Last year of Propagation = 2026 (yr)
Returned Error Message: Object reentered

04 22 2015; 22:53:57PM Science and Engineering - Orbit Lifetime/Dwell Time

INPUT

Start Year = 2015.500000 (yr)
Perigee Altitude = 600.000000 (km)
Apogee Altitude = 600.000000 (km)
Inclination = 98.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.007400 (m²/kg)

OUTPUT

Orbital Lifetime from Startyr = 19.805613 (yr)
Time Spent in LEO during Lifetime = 19.805613 (yr)
Last year of Propagation = 2035 (yr)
Returned Error Message: Object reentered

04 22 2015; 22:55:47PM Mission Editor Changes Applied
04 22 2015; 22:56:24PM Mission Editor Changes Applied
04 22 2015; 22:56:28PM Project Data Saved To File
04 22 2015; 22:56:48PM Processing Requirement 4.3-1: Return Status :
Not Run

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

=====
End of Requirement 4.3-1
04 22 2015; 22:56:51PM Processing Requirement 4.3-2: Return Status :
Passed

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

=====
End of Requirement 4.3-2
04 22 2015; 22:56:53PM Requirement 4.4-3: Compliant

=====
End of Requirement 4.4-3
04 22 2015; 22:57:01PM Processing Requirement 4.5-1: Return Status :
Passed

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

INPUT

Space Structure Name = Lemur2_PSLV
Space Structure Type = Payload
Perigee Altitude = 650.000000 (km)
Apogee Altitude = 650.000000 (km)
Inclination = 6.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.020800 (m²/kg)
Start Year = 2015.500000 (yr)
Initial Mass = 4.500000 (kg)
Final Mass = 4.500000 (kg)
Duration = 17.300000 (yr)
Station-Kept = False
Abandoned = True
PMD Perigee Altitude = -1.000000 (km)
PMD Apogee Altitude = -1.000000 (km)
PMD Inclination = 0.000000 (deg)
PMD RAAN = 0.000000 (deg)
PMD Argument of Perigee = 0.000000 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Collision Probability = 0.000002
Returned Error Message: Normal Processing
Date Range Error Message: Normal Date Range
Status = Pass

=====

INPUT

Space Structure Name = Lemur2_Soyuz
Space Structure Type = Payload
Perigee Altitude = 600.000000 (km)
Apogee Altitude = 600.000000 (km)
Inclination = 97.800000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.020800 (m²/kg)
Start Year = 2015.500000 (yr)
Initial Mass = 4.500000 (kg)
Final Mass = 4.500000 (kg)
Duration = 8.300000 (yr)

Station-Kept = False
Abandoned = True
PMD Perigee Altitude = -1.000000 (km)
PMD Apogee Altitude = -1.000000 (km)
PMD Inclination = 0.000000 (deg)
PMD RAAN = 0.000000 (deg)
PMD Argument of Perigee = 0.000000 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Collision Probability = 0.000002
Returned Error Message: Normal Processing
Date Range Error Message: Normal Date Range
Status = Pass

=====

INPUT

Space Structure Name = Lemur2_Falcon9
Space Structure Type = Payload
Perigee Altitude = 425.000000 (km)
Apogee Altitude = 750.000000 (km)
Inclination = 97.100000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.020800 (m²/kg)
Start Year = 2015.500000 (yr)
Initial Mass = 4.500000 (kg)
Final Mass = 4.500000 (kg)
Duration = 6.900000 (yr)
Station-Kept = False
Abandoned = True
PMD Perigee Altitude = -1.000000 (km)
PMD Apogee Altitude = -1.000000 (km)
PMD Inclination = 0.000000 (deg)
PMD RAAN = 0.000000 (deg)
PMD Argument of Perigee = 0.000000 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Collision Probability = 0.000001
Returned Error Message: Normal Processing
Date Range Error Message: Normal Date Range
Status = Pass

=====

INPUT

Space Structure Name = Lemur2_HIIB
Space Structure Type = Payload
Perigee Altitude = 575.000000 (km)
Apogee Altitude = 575.000000 (km)
Inclination = 31.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.020800 (m²/kg)
Start Year = 2015.500000 (yr)
Initial Mass = 4.500000 (kg)
Final Mass = 4.500000 (kg)
Duration = 7.500000 (yr)
Station-Kept = False
Abandoned = True
PMD Perigee Altitude = -1.000000 (km)
PMD Apogee Altitude = -1.000000 (km)
PMD Inclination = 0.000000 (deg)
PMD RAAN = 0.000000 (deg)
PMD Argument of Perigee = 0.000000 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Collision Probability = 0.000001
Returned Error Message: Normal Processing
Date Range Error Message: Normal Date Range
Status = Pass

=====

INPUT

Space Structure Name = Lemur2_AtlasV
Space Structure Type = Payload
Perigee Altitude = 500.000000 (km)
Apogee Altitude = 500.000000 (km)
Inclination = 51.600000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.020800 (m²/kg)
Start Year = 2015.500000 (yr)

Initial Mass = 4.500000 (kg)
Final Mass = 4.500000 (kg)
Duration = 5.200000 (yr)
Station-Kept = False
Abandoned = True
PMD Perigee Altitude = -1.000000 (km)
PMD Apogee Altitude = -1.000000 (km)
PMD Inclination = 0.000000 (deg)
PMD RAAN = 0.000000 (deg)
PMD Argument of Perigee = 0.000000 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Collision Probability = 0.000000
Returned Error Message: Normal Processing
Date Range Error Message: Normal Date Range
Status = Pass

=====

INPUT

Space Structure Name = Lemur2_Soyuz2
Space Structure Type = Payload
Perigee Altitude = 600.000000 (km)
Apogee Altitude = 600.000000 (km)
Inclination = 98.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.020800 (m²/kg)
Start Year = 2015.500000 (yr)
Initial Mass = 4.500000 (kg)
Final Mass = 4.500000 (kg)
Duration = 8.300000 (yr)
Station-Kept = False
Abandoned = True
PMD Perigee Altitude = -1.000000 (km)
PMD Apogee Altitude = -1.000000 (km)
PMD Inclination = 0.000000 (deg)
PMD RAAN = 0.000000 (deg)
PMD Argument of Perigee = 0.000000 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Collision Probability = 0.000002

Returned Error Message: Normal Processing
Date Range Error Message: Normal Date Range
Status = Pass

=====

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

04 22 2015; 22:57:09PM Requirement 4.5-2: Compliant
04 22 2015; 22:57:12PM Processing Requirement 4.6 Return Status :
Passed

=====

Project Data

=====

INPUT

Space Structure Name = Lemur2_PSLV
Space Structure Type = Payload

Perigee Altitude = 650.000000 (km)
Apogee Altitude = 650.000000 (km)
Inclination = 6.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.020800 (m²/kg)
Start Year = 2015.500000 (yr)
Initial Mass = 4.500000 (kg)
Final Mass = 4.500000 (kg)
Duration = 17.300000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = -1.000000 (km)
PMD Apogee Altitude = -1.000000 (km)
PMD Inclination = 0.000000 (deg)
PMD RAAN = 0.000000 (deg)
PMD Argument of Perigee = 0.000000 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 650.000000 (km)
Suggested Apogee Altitude = 650.000000 (km)
Returned Error Message = Reentry during mission (no PMD req.).

Released Year = 2032 (yr)
Requirement = 61

Compliance Status = Pass

=====

INPUT

Space Structure Name = Lemur2_Soyuz
Space Structure Type = Payload

Perigee Altitude = 600.000000 (km)
Apogee Altitude = 600.000000 (km)
Inclination = 97.800000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.020800 (m²/kg)
Start Year = 2015.500000 (yr)
Initial Mass = 4.500000 (kg)
Final Mass = 4.500000 (kg)
Duration = 8.300000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = -1.000000 (km)
PMD Apogee Altitude = -1.000000 (km)
PMD Inclination = 0.000000 (deg)
PMD RAAN = 0.000000 (deg)
PMD Argument of Perigee = 0.000000 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 600.000000 (km)
Suggested Apogee Altitude = 600.000000 (km)
Returned Error Message = Reentry during mission (no PMD req.).

Released Year = 2023 (yr)
Requirement = 61
Compliance Status = Pass

=====

INPUT

Space Structure Name = Lemur2_Falcon9
Space Structure Type = Payload

Perigee Altitude = 425.000000 (km)
Apogee Altitude = 750.000000 (km)

Inclination = 97.100000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.020800 (m²/kg)
Start Year = 2015.500000 (yr)
Initial Mass = 4.500000 (kg)
Final Mass = 4.500000 (kg)
Duration = 6.900000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = -1.000000 (km)
PMD Apogee Altitude = -1.000000 (km)
PMD Inclination = 0.000000 (deg)
PMD RAAN = 0.000000 (deg)
PMD Argument of Perigee = 0.000000 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 425.000000 (km)
Suggested Apogee Altitude = 750.000000 (km)
Returned Error Message = Reentry during mission (no PMD req.).

Released Year = 2021 (yr)
Requirement = 61
Compliance Status = Pass

=====

INPUT

Space Structure Name = Lemur2_HIIB
Space Structure Type = Payload

Perigee Altitude = 575.000000 (km)
Apogee Altitude = 575.000000 (km)
Inclination = 31.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.020800 (m²/kg)
Start Year = 2015.500000 (yr)
Initial Mass = 4.500000 (kg)
Final Mass = 4.500000 (kg)
Duration = 7.500000 (yr)
Station Kept = False
Abandoned = True

PMD Perigee Altitude = -1.000000 (km)
PMD Apogee Altitude = -1.000000 (km)
PMD Inclination = 0.000000 (deg)
PMD RAAN = 0.000000 (deg)
PMD Argument of Perigee = 0.000000 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 575.000000 (km)
Suggested Apogee Altitude = 575.000000 (km)
Returned Error Message = Reentry during mission (no PMD req.).

Released Year = 2022 (yr)
Requirement = 61
Compliance Status = Pass

=====

INPUT

Space Structure Name = Lemur2_AtlasV
Space Structure Type = Payload

Perigee Altitude = 500.000000 (km)
Apogee Altitude = 500.000000 (km)
Inclination = 51.600000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.020800 (m²/kg)
Start Year = 2015.500000 (yr)
Initial Mass = 4.500000 (kg)
Final Mass = 4.500000 (kg)
Duration = 5.200000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 248.048791 (km)
PMD Apogee Altitude = 256.789865 (km)
PMD Inclination = 51.571325 (deg)
PMD RAAN = 7.848664 (deg)
PMD Argument of Perigee = 74.605471 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 248.048791 (km)
Suggested Apogee Altitude = 256.789865 (km)

Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2020 (yr)

Requirement = 61

Compliance Status = Pass

=====

INPUT

Space Structure Name = Lemur2_Soyuz2

Space Structure Type = Payload

Perigee Altitude = 600.000000 (km)

Apogee Altitude = 600.000000 (km)

Inclination = 98.000000 (deg)

RAAN = 0.000000 (deg)

Argument of Perigee = 0.000000 (deg)

Mean Anomaly = 0.000000 (deg)

Area-To-Mass Ratio = 0.020800 (m²/kg)

Start Year = 2015.500000 (yr)

Initial Mass = 4.500000 (kg)

Final Mass = 4.500000 (kg)

Duration = 8.300000 (yr)

Station Kept = False

Abandoned = True

PMD Perigee Altitude = -1.000000 (km)

PMD Apogee Altitude = -1.000000 (km)

PMD Inclination = 0.000000 (deg)

PMD RAAN = 0.000000 (deg)

PMD Argument of Perigee = 0.000000 (deg)

PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 600.000000 (km)

Suggested Apogee Altitude = 600.000000 (km)

Returned Error Message = Reentry during mission (no PMD req.).

Released Year = 2023 (yr)

Requirement = 61

Compliance Status = Pass

=====

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

04 22 2015; 22:58:19PM *****Processing Requirement 4.7-1

Return Status : Passed

*****INPUT*****

Item Number = 1

name = Lemur2_PSLV
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 4.500000
Thermal Mass = 4.500000
Diameter/Width = 0.100000
Length = 0.340000
Height = 0.100000

name = Structure_tray
quantity = 2
parent = 1
materialID = 9
type = Box
Aero Mass = 0.200000
Thermal Mass = 0.200000
Diameter/Width = 0.100000
Length = 0.340000
Height = 0.005000

name = Structure_ribs
quantity = 10
parent = 1
materialID = 9
type = Box
Aero Mass = 0.010000
Thermal Mass = 0.010000
Diameter/Width = 0.012000
Length = 0.083000
Height = 0.006000

name = Structure_mountingplates
quantity = 5
parent = 1
materialID = 9
type = Flat Plate
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.080000
Length = 0.100000

name = PCB

quantity = 15
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.080000
Thermal Mass = 0.080000
Diameter/Width = 0.080000
Length = 0.080000

name = Lenses
quantity = 2
parent = 1
materialID = 9
type = Cylinder
Aero Mass = 0.200000
Thermal Mass = 0.200000
Diameter/Width = 0.030000
Length = 0.120000

name = Reaction Wheels
quantity = 3
parent = 1
materialID = 67
type = Cylinder
Aero Mass = 0.120000
Thermal Mass = 0.120000
Diameter/Width = 0.030000
Length = 0.020000

name = solar_panels
quantity = 6
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.083000
Length = 0.324000

name = solar_cells
quantity = 61
parent = 1
materialID = 24
type = Flat Plate
Aero Mass = 0.015000
Thermal Mass = 0.015000
Diameter/Width = 0.040000
Length = 0.080000

*****OUTPUT****

Item Number = 1

name = Lemur2_PSLV
Demise Altitude = 77.996621
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = Structure_tray
Demise Altitude = 76.444527
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = Structure_ribs
Demise Altitude = 77.121871
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = Structure_mountingplates
Demise Altitude = 75.443886
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = PCB
Demise Altitude = 76.127535
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = Lenses
Demise Altitude = 72.843566
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = Reaction Wheels
Demise Altitude = 0.000000
Debris Casualty Area = 1.169982
Impact Kinetic Energy = 202.520203

name = solar_panels
Demise Altitude = 77.271605

Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = solar_cells
Demise Altitude = 77.747871
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*****INPUT****
Item Number = 2

name = Lemur2_Soyuz
quantity = 1
parent = 0
materialID = 9
type = Box
Aero Mass = 4.500000
Thermal Mass = 4.500000
Diameter/Width = 0.100000
Length = 0.340000
Height = 0.100000

name = Lemur2_Soyuz
quantity = 1
parent = 1
materialID = 9
type = Box
Aero Mass = 4.500000
Thermal Mass = 4.500000
Diameter/Width = 0.100000
Length = 0.340000
Height = 0.100000

*****OUTPUT****
Item Number = 2

name = Lemur2_Soyuz
Demise Altitude = 77.998722
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = Lemur2_Soyuz
Demise Altitude = 66.439011
Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

*****INPUT****

Item Number = 3

name = Lemur2_Falcon9
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 4.500000
Thermal Mass = 4.500000
Diameter/Width = 0.100000
Length = 0.340000
Height = 0.100000

name = Lemur2_Falcon9
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 4.500000
Thermal Mass = 4.500000
Diameter/Width = 0.100000
Length = 0.340000
Height = 0.100000

*****OUTPUT****

Item Number = 3

name = Lemur2_Falcon9
Demise Altitude = 77.997660
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = Lemur2_Falcon9
Demise Altitude = 64.797706
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*****INPUT****

Item Number = 4

name = Lemur2_HIIB
quantity = 1
parent = 0
materialID = 9
type = Box
Aero Mass = 4.500000
Thermal Mass = 4.500000
Diameter/Width = 0.100000
Length = 0.340000
Height = 0.100000

name = Lemur2_HIIB
quantity = 1
parent = 1
materialID = 9
type = Box
Aero Mass = 4.500000
Thermal Mass = 4.500000
Diameter/Width = 0.100000
Length = 0.340000
Height = 0.100000

*****OUTPUT****

Item Number = 4

name = Lemur2_HIIB
Demise Altitude = 77.995176
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = Lemur2_HIIB
Demise Altitude = 64.728616
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*****INPUT****

Item Number = 5

name = Lemur2_AtlasV
quantity = 1
parent = 0
materialID = 9
type = Box
Aero Mass = 4.500000
Thermal Mass = 4.500000

Diameter/Width = 0.100000
Length = 0.340000
Height = 0.100000

name = Lemur2_AtlasV
quantity = 1
parent = 1
materialID = 9
type = Box
Aero Mass = 4.500000
Thermal Mass = 4.500000
Diameter/Width = 0.100000
Length = 0.340000
Height = 0.100000

*****OUTPUT****

Item Number = 5

name = Lemur2_AtlasV
Demise Altitude = 77.993738
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = Lemur2_AtlasV
Demise Altitude = 65.304866
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*****INPUT****

Item Number = 6

name = Lemur2_Soyuz2
quantity = 1
parent = 0
materialID = 9
type = Box
Aero Mass = 4.500000
Thermal Mass = 4.500000
Diameter/Width = 0.100000
Length = 0.340000
Height = 0.100000

name = Lemur2_Soyuz2
quantity = 1
parent = 1

materialID = 9
type = Box
Aero Mass = 4.500000
Thermal Mass = 4.500000
Diameter/Width = 0.100000
Length = 0.340000
Height = 0.100000

*****OUTPUT****

Item Number = 6

name = Lemur2_Soyuz2
Demise Altitude = 77.997137
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = Lemur2_Soyuz2
Demise Altitude = 66.448152
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

=====
===== End of Requirement 4.7-1 =====