

Orbital Debris Assessment

Astranis DemoSat-2

Overview

The Astranis DemoSat-2 test satellite is being launched to a 500 km circular, sun-synchronous orbit, and will be deployed by a standard QuadPack satellite dispenser. The satellite does not have propulsion, pressure vessels, detachable components, or any other similar potential sources of debris. The spacecraft conforms to the form factor of a 3U cubesat (35 cm X 10 cm X 10 cm in size), and spacecraft mass of 5 kg was used. All calculations were done using NASA's DAS (Debris Assessment Software) program, see the following pages for screenshots of the program outputs.

An orbital lifetime calculation for this orbit estimates that the satellite will remain on orbit for approximately 6.4 years in the nominal case. In this case, the satellite is assumed to be tumbling and the calculation was done with an average cross-sectional area with 20% factor applied for conservatism, per the ISO/ANSI draft standard 27852:2010(E). In the worst case, in which the satellite is somehow able to present its smallest cross-section to its direction of travel for its entire life on orbit, analysis shows the satellite would remain on orbit for 17.3 years. The satellite has four small deployable monopole antennas, which were not considered in this analysis. These antennas would be expected to have a measurable effect, reducing the lifetime further.

Collision risk analysis was performed using the DAS software, which showed a collision probability of 0.0000 in both the nominal and worst case lifetime scenarios. An atmospheric demise analysis was completed as well, showing a de minimis risk of human casualties.

To support collision avoidance, Astranis will be in communication with JSpOC directly to provide orbital parameters and any other assistance necessary for the cataloging of the satellite. An Astranis employee will be assigned as the point of contact for communications with JSpOC regarding conjunction warnings.

Orbital Lifetime Calculation

NASA DAS software was used to conduct an orbital lifetime analysis. Two scenarios were contemplated, a nominal case and a worst case.

For the nominal case, the spacecraft was assumed to be tumbling and an average cross-sectional area was used. To determine the mean cross-sectional area of a tumbling rectangular parallelepiped, the approach in ISO/ANSI draft standard 27852:2010(E) was taken. The formula for the average cross-sectional area in that case is $(S1+S2+S3)/2$, with an additional factor of 20% applied for conservatism. This gave an area-to-mass ratio of 0.0064 m²/kg.

For the worst case, it was assumed that the spacecraft was somehow able to present its minimal cross-sectional area of 10 cm X 10 cm for the duration of its orbital lifetime. This gave an area-to-mass ratio of 0.0020 m²/kg.

| Spacecraft Dimensions and Mass | |
|---------------------------------------|---------------------------|
| Length | 35 cm |
| Width | 10 cm |
| Height | 10 cm |
| Mass | 5 kg |
| Calculated Parameters | |
| Nominal Area-to-Mass Ratio | 0.0064 m ² /kg |
| Worst case Area-to-Mass Ratio | 0.0020 m ² /kg |
| Orbit Overview | |
| Altitude | 500 km |
| Inclination | 97.4 deg |
| Orbit Lifetime | |
| Nominal | 6.4 years |
| Worst case | 17.3 years |

Nominal scenario (average cross-sectional area is used)

The screenshot shows the 'Orbit Lifetime/Dwell Time' configuration window in the ASTRANIS software. The window is titled 'DAS - AstranisProject3U - [Science and Engineering Utilities]'. The left sidebar shows a tree view of various utilities, with 'Orbit Lifetime/Dwell Time' selected. The main area contains input and output fields for orbital parameters.

Input Parameters:

- Start Year [ex:]: 2017.416
- Perigee: 500 km
- Apogee Altitude: 500 km
- Inclination: 97.4 deg
- R. A. of Ascending Node: 0 deg
- Argument of: 0 deg
- Area-to-Mass: 0.0064 m²/kg

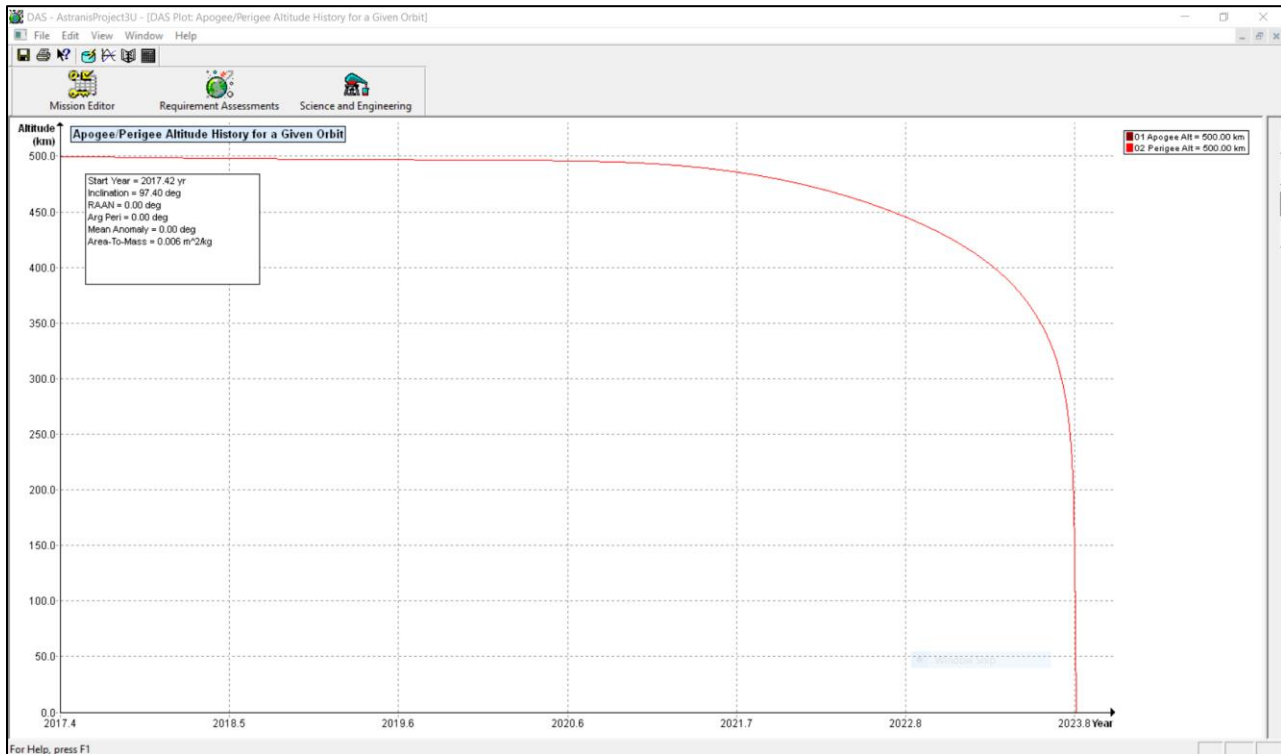
Output Parameters:

- Calculated Orbit: 6.412 yr
- Calculated Orbit Dwell: 6.412 yr
- Last year of: 2023 yr

Messages: Object reentered.

Buttons: Run, Reset, Help

For Help, press F1



Worst case scenario (minimal cross-sectional area is used)

DAS - AstranisProject3U - [Science and Engineering Utilities]

File Edit View Window Help

Mission Editor Requirement Assessments Science and Engineering

Science and Engineering Utilities

- On-Orbit Collisions
 - Debris Impacts vs. Orbit Altitude
 - Debris Impacts vs. Debris Diameter
 - Debris Impacts vs. Date
- Analysis of Postmission Disposal Maneuvers
 - Disposal by Atmospheric Reentry
 - Maneuver to Storage Orbit
 - Reentry Survivability Analysis
- Orbit Evolution Analysis
 - Apogee/Perigee Altitude History for a Given Orbit
 - Orbit Lifetime/Dwell Time
- Delta-V Postmission Maneuver Analysis
 - Delta-V for Decay Orbit Given Orbital Lifetime
 - Delta-V for Decay Orbit Given Area-To-Mass
- Delta-V Orbit to Orbit Transfer
 - Orbit to Orbit Transfer
- Other Utilities
 - TLE Converter
 - Calculate Cross-Sectional Area

Orbit Lifetime/Dwell Time

Input

Start Year [ex: 2017.416]

Perigee 500 km

Apogee Altitude 500 km

Inclination 97.4 deg

R. A. of Ascending Node 0 deg

Argument of 0 deg

Area-to-Mass 0.0020 m²/kg

Run Reset Help

Output

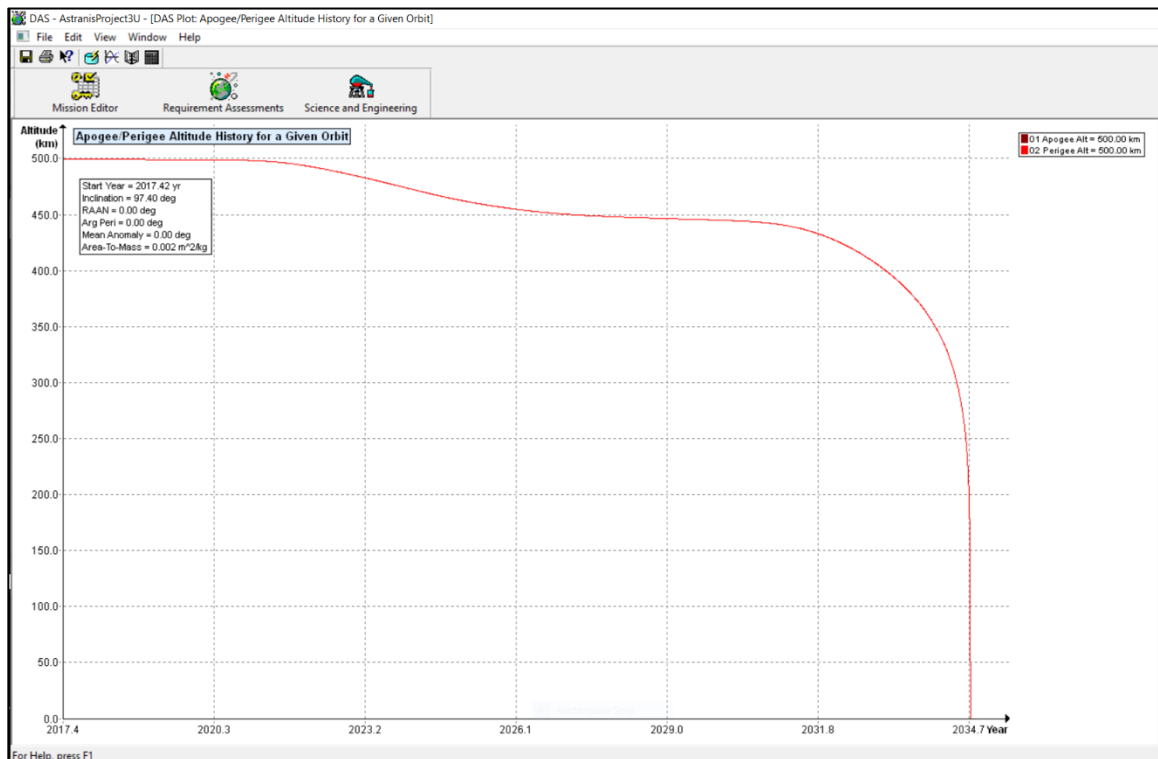
Calculated Orbit 17.298 yr

Calculated Orbit Dwell 17.298 yr

Last year of 2034 yr

Messages

Object reentered.



Collision Risk Calculation

The DAS Software was used to calculate the probability of spacecraft collision with large objects. As before two cases were analyzed—a nominal case assuming the spacecraft is tumbling, and therefore has a shorter life, and a worst-case scenario in which the spacecraft has a longer life. In both cases, the DAS Software found the probability of a collision to be 0.0000.

Nominal scenario (average cross-sectional area is used).

The screenshot displays the DAS software interface for requirement assessments. The main window is titled "[Requirement 4.5-1] Limiting Debris Generated by Collisions with Large Objects".

Input Section:

- Start: 2017.416

| | Space | Perigee | Apogee | Inclination | RAAN | Argument of | Mission | Final Area-To-Mass | Final |
|---------------------|-----------|---------|--------|-------------|-------|---------------|----------------|----------------------------|-----------|
| | Structure | (km) | (km) | (deg) | (deg) | Perigee (deg) | Duration (yrs) | Ratio (m ² /kg) | Mass (kg) |
| Astranis-3U-Demo... | Payload | 500 | 500 | 97.4 | | | 6.41 | 0.0064 | 5 |

Output Section:

| | Space | Compliance | Collision |
|---------------------|-----------|------------|-------------|
| | Structure | Status | Probability |
| Astranis-3U-Demo... | Payload | Compliant | 0.00000 |

Messages Section:

Requirement 4.5-1: Compliant - Astranis-3U-DemoSat

Worst case scenario (minimal cross-sectional area is used).

The screenshot displays the DAS software interface for Requirement Assessments. The main window is titled "[Requirement 4.5-1] Limiting Debris Generated by Collisions with Large Objects". The "Input" section shows a start date of 2017.416 and a table of orbital parameters for the Astranis-3U Payload. The "Output" section shows a table of compliance results, indicating that the spacecraft is compliant with a collision probability of 0.00000. The "Messages" section at the bottom displays the message: "Requirement 4.5-1: Compliant - Astranis-3U".

| Space | Perigee | Apogee | Inclination | RAAN | Argument of Perigee | Mission Duration | Final Area-To-Mass Ratio | Final Mass |
|---------------------|---------|--------|-------------|-------|---------------------|------------------|--------------------------|------------|
| | (km) | (km) | (deg) | (deg) | (deg) | (yrs) | (m ² /kg) | (kg) |
| Astranis-3U Payload | 500 | 500 | 97.4 | | | 17.30 | 0.0020 | 5 |

| Space | Compliance | Collision |
|---------------------|------------|-------------|
| Structure | Status | Probability |
| Astranis-3U Payload | Compliant | 0.00000 |

Ground Impact Risk Assessment

Given the spacecraft's small mass (5 kg) and the makeup of its constituent components (see table below), the spacecraft is expected to break up upon re-entry and for very little, if any, components to make it to the ground.

The DAS analysis found the risk of human casualty to be de minimis and in compliance with Requirement 4.7-1, with only one component found to make it to ground level with a kinetic energy of 2 Joules.

The Astranis DemoSat-2 spacecraft components include:

| Name | Qty | Material | Dimensions (m) | Mass per | Mass total |
|--------------------------------|-----|------------|--|----------|----------------|
| Main bulkhead | 1 | Al | 0.10 x 0.10 x 0.10 | 0.240 | 0.240 |
| Payload enclosure | 1 | Al | 0.20 x 0.075 x 0.055 | 1.000 | 1.000 |
| Front plate | 1 | Al | 0.10 x 0.10 x 0.002 | 0.020 | 0.020 |
| Back plate | 1 | Al | 0.10 x 0.10 x 0.01 | 0.070 | 0.070 |
| Torque Coil | 3 | Copper | 0.10 x 0.10 x 0.02 | 0.150 | 0.450 |
| Solar Panels-GaAs Photovoltaic | 4 | GaAs | 0.35 x 0.10 x 0.0015 | 0.055 | 0.220 |
| Solar Panels-Fiberglass Cover | 4 | Fiberglass | 0.35 x 0.10 x 0.0015 | 0.055 | 0.220 |
| Motors-Steel Portion | 4 | Steel | 0.025 x 0.025 x 0.0075 | 0.010 | 0.040 |
| Motors-Copper Portion | 4 | Copper | 0.025 x 0.025 x 0.0075 | 0.010 | 0.040 |
| Solenoid-Steel Portion | 4 | Steel | 0.02 x 0.02 x 0.02 | 0.0225 | 0.090 |
| Solenoid-Copper Portion | 4 | Copper | 0.02 x 0.02 x 0.02 | 0.0225 | 0.090 |
| Batteries (18650) | 4 | Al | (18650 cell) Cylinder, Dia=0.018, Ht=0.065 | 0.040 | 0.160 |
| Brackets | 20 | Al 6061 | Default based on density: 0.03x0.03x0.03 | 0.050 | 1.000 |
| PCBAs | 8 | Fiberglass | 0.10 x 0.10 x 0.01 | 0.050 | 0.400 |
| Total mass | | | | | 4.34 kg |

DAS Screenshots Page 1 (inputs to ground impact risk assessment program)

NS 8719.14 - Process for Limiting Orbital Debris

- (Requirement 4.3-1) - Mission-Related Debris Passing Through LEO
- (Requirement 4.3-2) - Mission-Related Debris Passing Near GEO
- (Requirement 4.4-3) - Long-Term Risk from Planned Breakups
- (Requirement 4.5-1) - Probability of Collision With Large Objects
- (Requirements 4.5-2) - Probability of Damage from Small Objects
- (Requirements 4.6-1 to 4.6-3) - Postmission Disposal
- (Requirement 4.7-1) - Casualty Risk from Reentry Debris
- (Requirement 4.8-1) - Collision Hazards of Space Tethers

| Name | Quantity | Material Type | Object Sha... | Thermal Mass (kg) | Diameter/Width (m) | Length (m) | Height (m) |
|----------------------------------|----------|--------------------|---------------|-------------------|--------------------|------------|------------|
| 1 Astranis-3U-DemoSat | 1 | Aluminum (generic) | Box | 5 | 0.10 | 0.35 | 0.10 |
| 2 Rail | 4 | Aluminum (generic) | Box | 0.075 | 0.02 | 0.35 | 0.02 |
| 3 Main bulkhead | 1 | Aluminum (generic) | Box | 0.240 | 0.1 | 0.1 | 0.1 |
| 4 Payload enclosure | 1 | Aluminum (generic) | Box | 1.000 | 0.075 | 0.2 | 0.055 |
| 5 Front plate | 1 | Aluminum (generic) | Box | 0.020 | 0.1 | 0.1 | 0.002 |
| 6 Back plate | 1 | Aluminum (generic) | Box | 0.070 | 0.1 | 0.1 | 0.01 |
| 7 Torque coil | 3 | Copper Alloy | Box | 0.150 | 0.1 | 0.1 | 0.02 |
| 8 Solar Panels-GaAs Photovoltaic | 4 | GaAs | Box | 0.055 | 0.1 | 0.35 | 0.0015 |
| 9 Solar Panels-Fiberglass Cover | 4 | Fiberglass | Box | 0.055 | 0.1 | 0.35 | 0.0015 |

Buttons: Run, Requirement, Help

Output

For Help, press F1

NS 8719.14 - Process for Limiting Orbital Debris

- (Requirement 4.3-2) - Mission-Related Debris Passing Near GEO
- (Requirement 4.4-3) - Long-Term Risk from Planned Breakups
- (Requirement 4.5-1) - Probability of Collision With Large Objects
- (Requirements 4.5-2) - Probability of Damage from Small Objects
- (Requirements 4.6-1 to 4.6-3) - Postmission Disposal
- (Requirement 4.7-1) - Casualty Risk from Reentry Debris
- (Requirement 4.8-1) - Collision Hazards of Space Tethers

| Name | Quantity | Material Type | Object Sha... | Thermal Mass (kg) | Diameter/Width (m) | Length (m) | Height (m) |
|----------------------------------|----------|---------------------------|---------------|-------------------|--------------------|------------|------------|
| 8 Solar Panels-GaAs Photovoltaic | 4 | GaAs | Box | 0.055 | 0.1 | 0.35 | 0.0015 |
| 9 Solar Panels-Fiberglass Cover | 4 | Fiberglass | Box | 0.055 | 0.1 | 0.35 | 0.0015 |
| 10 Motors-Steel Portion | 4 | Stainless Steel (generic) | Box | 0.010 | 0.025 | 0.025 | 0.0075 |
| 11 Motors-Copper Portion | 4 | Copper Alloy | Box | 0.010 | 0.025 | 0.025 | 0.0075 |
| 12 Solenoid-Steel Portion | 4 | Stainless Steel (generic) | Box | 0.0225 | 0.02 | 0.02 | 0.02 |
| 13 Solenoid-Copper Portion | 4 | Copper Alloy | Box | 0.0225 | 0.02 | 0.02 | 0.02 |
| 14 Batteries (18650) | 4 | Aluminum (generic) | Cylinder | 0.040 | 0.018 | 0.065 | |
| 15 Brackets | 20 | Aluminum 6061-T6 | Box | 0.050 | 0.03 | 0.03 | 0.03 |
| 16 PCBAs | 8 | Fiberglass | Box | 0.050 | 0.1 | 0.1 | 0.01 |

Buttons: Run, Requirement, Help

Output

For Help, press F1

DAS Screenshots Page 2 (outputs of ground impact risk assessment program)

DAS - AstranisProject3U - [Requirement Assessments]

File Edit View Window Help

Mission Editor Requirement Assessments Science and Engineering

NS 8719.14 - Process for Limiting Orbital Debris

- (Requirement 4.3-1) - Mission-Related Debris Passing Through LEO
- (Requirement 4.3-2) - Mission-Related Debris Passing Near GEO
- (Requirement 4.4-3) - Long-Term Risk from Planned Breakups
- (Requirement 4.5-1) - Probability of Collision With Large Objects
- (Requirement 4.5-2) - Probability of Damage from Small Objects
- (Requirements 4.6-1 to 4.6-3) - Postmission Disposal
- (Requirement 4.7-1) - Casualty Risk from Reentry Debris
- (Requirement 4.8-1) - Collision Hazards of Space Tethers

Component Data

| Name | Quantity | Material Type | Object Sha... | Thermal Mass (kg) | Diameter/Width (m) | Length (m) | Height (m) |
|----------------------------------|----------|---------------------------|---------------|-------------------|--------------------|------------|------------|
| 2 Rail | 4 | Aluminum (generic) | Box | 0.075 | 0.02 | 0.35 | 0.02 |
| 3 Main bulkhead | 1 | Aluminum (generic) | Box | 0.240 | 0.1 | 0.1 | 0.1 |
| 4 Payload enclosure | 1 | Aluminum (generic) | Box | 1.000 | 0.075 | 0.2 | 0.055 |
| 5 Front plate | 1 | Aluminum (generic) | Box | 0.020 | 0.1 | 0.1 | 0.002 |
| 6 Back plate | 1 | Aluminum (generic) | Box | 0.070 | 0.1 | 0.1 | 0.01 |
| 7 Torque coil | 3 | Copper Alloy | Box | 0.150 | 0.1 | 0.1 | 0.02 |
| 8 Solar Panels-GaAs Photovoltaic | 4 | GaAs | Box | 0.055 | 0.1 | 0.35 | 0.0015 |
| 9 Solar Panels-Fiberglass Cover | 4 | Fiberglass | Box | 0.055 | 0.1 | 0.35 | 0.0015 |
| 10 Motors-Steel Portion | 4 | Stainless Steel (generic) | Box | 0.010 | 0.025 | 0.025 | 0.0075 |

Run Requirement Help

Output

| Object Name | Compliance Status | Risk of Human Casualty | Sub-Component Object | Demise Altitude (km) | Total Debris Casualty Area ... | Kinetic Energy (J) |
|------------------|-------------------|------------------------|---------------------------|----------------------|--------------------------------|--------------------|
| Astranis-3U-D... | Compliant | 1:0 | | | 0.00 | |
| | | | Rail | 77.2 | 0.00 | 0 |
| | | | Main bulkhead | 75.8 | 0.00 | 0 |
| | | | Payload enclosure | 71.3 | 0.00 | 0 |
| | | | Front plate | 77.6 | 0.00 | 0 |
| | | | Back plate | 76.6 | 0.00 | 0 |
| | | | Torque coil | 76.0 | 0.00 | 0 |
| | | | Solar Panels-GaAs Phot... | 77.6 | 0.00 | 0 |

Messages

Astranis-3U-DemoSat Requirement 4.7-1 Compliant

For Help, press F1

DAS - AstranisProject3U - [Requirement Assessments]

File Edit View Window Help

Mission Editor Requirement Assessments Science and Engineering

NS 8719.14 - Process for Limiting Orbital Debris

- (Requirement 4.3-1) - Mission-Related Debris Passing Through LEO
- (Requirement 4.3-2) - Mission-Related Debris Passing Near GEO
- (Requirement 4.4-3) - Long-Term Risk from Planned Breakups
- (Requirement 4.5-1) - Probability of Collision With Large Objects
- (Requirement 4.5-2) - Probability of Damage from Small Objects
- (Requirements 4.6-1 to 4.6-3) - Postmission Disposal
- (Requirement 4.7-1) - Casualty Risk from Reentry Debris
- (Requirement 4.8-1) - Collision Hazards of Space Tethers

Component Data

| Name | Quantity | Material Type | Object Sha... | Thermal Mass (kg) | Diameter/Width (m) | Length (m) | Height (m) |
|----------------------------------|----------|---------------------------|---------------|-------------------|--------------------|------------|------------|
| 8 Solar Panels-GaAs Photovoltaic | 4 | GaAs | Box | 0.055 | 0.1 | 0.35 | 0.0015 |
| 9 Solar Panels-Fiberglass Cover | 4 | Fiberglass | Box | 0.055 | 0.1 | 0.35 | 0.0015 |
| 10 Motors-Steel Portion | 4 | Stainless Steel (generic) | Box | 0.010 | 0.025 | 0.025 | 0.0075 |
| 11 Motors-Copper Portion | 4 | Copper Alloy | Box | 0.010 | 0.025 | 0.025 | 0.0075 |
| 12 Solenoid-Steel Portion | 4 | Stainless Steel (generic) | Box | 0.0225 | 0.02 | 0.02 | 0.02 |
| 13 Solenoid-Copper Portion | 4 | Copper Alloy | Box | 0.0225 | 0.02 | 0.02 | 0.02 |
| 14 Batteries (18650) | 4 | Aluminum (generic) | Cylinder | 0.040 | 0.018 | 0.065 | |
| 15 Brackets | 20 | Aluminum 6061-T6 | Box | 0.050 | 0.03 | 0.03 | 0.03 |
| 16 PCBAs | 8 | Fiberglass | Box | 0.050 | 0.1 | 0.1 | 0.01 |

Run Requirement Help

Output

| Object Name | Compliance Status | Risk of Human Casualty | Sub-Component Object | Demise Altitude (km) | Total Debris Casualty Area ... | Kinetic Energy (J) |
|-------------|-------------------|------------------------|-------------------------|----------------------|--------------------------------|--------------------|
| | | | Motors-Steel Portion | 0.0 | 1.54 | 2 |
| | | | Motors-Copper Portion | 77.0 | 0.00 | 0 |
| | | | Solenoid-Steel Portion | 72.1 | 0.00 | 0 |
| | | | Solenoid-Copper Portion | 76.0 | 0.00 | 0 |
| | | | Batteries (18650) | 75.5 | 0.00 | 0 |
| | | | Brackets | 75.0 | 0.00 | 0 |
| | | | PCBAs | 77.4 | 0.00 | 0 |

Messages

Astranis-3U-DemoSat Requirement 4.7-1 Compliant

For Help, press F1