BlackSky Global Pathfinder-1 Orbital Debris Assessment Report (ODAR)

This report is presented in compliance with NASA-STD-8719.14, APPENDIX A.

Report Version: 4, March 5, 2016

Revision history:

Version	Date	Author	Description
1	10/29/13	Eric Lund	ODAR for Pathfinder spacecraft launched into an SSO orbit
2	5/14/14	John Springmann	Modifications due to new launch plan, which is deployment from the International Space Station
3	11/17/14	John Springmann	Modifications due to a new launch plan, which is secondary deployment from SpaceX Falcon 9
4	3/5/16	John Springmann	Modifications for the July 2016 PSLV launch of Pathfinder-1

DAS Software Version Used In Analysis: v2.0.2

VERSION APPROVAL and/or FINAL APPROVAL*:

Jason Andrews, CEO

*Approval signatures indicate acceptance of the ODAR-defined risk.

Table Contents

Self-assessment of the ODAR using the format in Appendix A.2 of NASA-STD- 8719.14:

A self-assessment is provided below in accordance with the assessment format provided in Appendix A.2 of NASA-STD-8719.14.

Orbital Debris Self-Assessment Report Evaluation: Pathfinder-1

Requirement #	Launch Vehicle				Spacecraft			Comments
	Compliant	Not Compliant	Incomplete	Standard Non Compliant	Compliant or N/A	Not Compliant	Incomplete	
4.3-1.a	☐	☐	☐	☐	☒	☐	☐	No Debris Released in LEO.
4.3-1.b	☐	☐	☐	☐	☒	☐	☐	No Debris Released in LEO.
4.3-2	☐	☐	☐	☐	☒	☐	☐	No Debris Released in GEO.
4.4-1	☐	☐	☐	☐	☒	☐	☐	Not applicable. See note 1.
4.4-2	☐	☐	☐	☐	☒	☐	☐	Warm-gas propulsion tank will be deplete during operations
4.4-3	☐	☐	☐	☐	☒	☐	☐	No planned breakups.
4.4-4	☐	☐	☐	☐	☒	☐	☐	No planned breakups.
4.5-1	☐	☐	☐	☐	☒	☐	☐	Collision probability 0.00000
4.5-2	☐	☐	☐	☐	☒	☐	☐	Damage probability < 0.0068
4.6-1(a)	☐	☐	☐	☐	☒	☐	☐	Natural forces cause atmospheric reentry
4.6-1(b)	☐	☐	☐	☐	☒	☐	☐	Not applicable.
4.6-1(c)	☐	☐	☐	☐	☒	☐	☐	Not applicable.
4.6-2	☐	☐	☐	☐	☒	☐	☐	Spacecraft does not go to GEO.
4.6-3	☐	☐	☐	☐	☒	☐	☐	Spacecraft does not go beyond LEO.
4.6-4	☐	☐	☐	☐	☒	☐	☐	Requirements 4.6-1 through 4.6-3 are met
4.7-1	☐	☐	☐	☐	☒	☐	☐	DAS reports human casualty probability < 1:10,000
4.8-1					☒	☐	☐	No tethers used.

Notes:

1. This launch has multiple spacecraft manifested; the Pathfinder-1 satellite is not the primary payload. No explosive devices are used to deploy the spacecraft.

Assessment Report Format:

ODAR Technical Sections Format Requirements:

BlackSky Global, LLC is a US company; this ODAR, for BlackSky Global's Pathfinder-1 satellite, follows the format recommended in NASA- STD-8719.14, Appendix A.1 and includes the content indicated at a minimum in each section 2 through 8 below. Sections 9 through 14 apply to the launch vehicle ODAR and are not covered here.

ODAR Section 1: Program Management and Mission Overview

Project Manager: Dr. John Springmann

Foreign government or space agency participation: none

Schedule of upcoming mission milestones:

FRR:	May 2016
Launch:	July 2016

Mission Overview:
Pathfinder is a commercial Earth observation satellite. There are two Pathfinder satellites, Pathfinder-1 and Pathfinder-2. This ODAR covers Pathfinder-1, which is launching on a PSLV rocket in July 2016 (Pathfinder-2 is launching on a SpaceX Falcon 9 and is covered in a separate ODAR). The satellite will be deployed into a 670 km circular, sun-synchronous orbit (98.21° inclination) with local time of descending note (LTDN) of 0930. After deployment into orbit and initial satellite checkout is complete, the satellite's propulsion systems (warm gas) will be used to lower the altitude to an orbit of 485 x 670 km. The planned mission duration is 36 months. At the end of its mission, the satellite will release any remaining propellant (which is expected to be depleted during operations) and rely on atmospheric drag to fully deorbit the spacecraft.

ODAR Summary: No debris released in normal operations; no credible scenario for breakups; the collision probability with other objects is compliant with NASA standards; and the estimated nominal decay lifetime due to atmospheric drag is under 25 years following operations (20 years after 3 years of nominal operations, as calculated by DAS 2.0.2).

Launch vehicle and launch site: PSLV, Satish Dhawan Space Centre, Sriharikota, India.

Proposed launch date: July 2016

Mission duration: Maximum Nominal Operations: 36 months, Post-Operations Orbit lifetime: 20 years until reentry via atmospheric orbital decay (23 years in total).

Launch and deployment profile, including all parking, transfer, and operational orbits with apogee, perigee, and inclination:

	Apogee Altitude	Perigee Altitude	Inclination	Comments
Deployment	670 km	670 km	98.21 deg	

Transfer Orbit	670 km	485 km	98.21 deg	The "transfer orbit" is simply a lowering of the perigee until the operational orbit is achieved
Operational Orbit	670 km	485 km	98.21 deg	
End-of-Life Orbit	670 km	485 km	98.21 deg	The end of life orbit is identical to the operational orbit. After operations complete, the satellite orbit will naturally decay.

ODAR Section 2: Spacecraft Description

Physical description of the spacecraft:

Pathfinder-1has a launch mass of 45.62 kg. Basic physical dimensions are 41 cm x 47.5 cm x 119 cm. A CAD model of the spacecraft is shown in Figure 1.

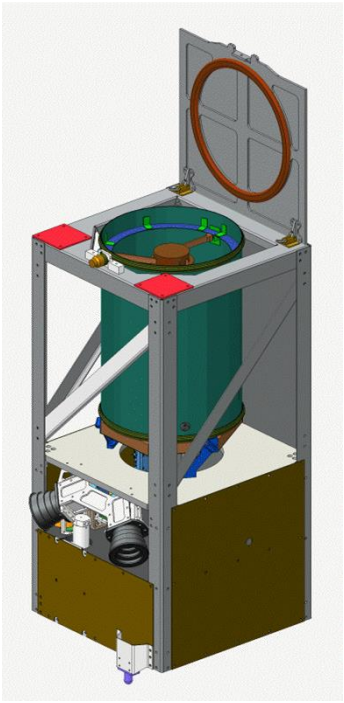

Figure 1. CAD model of the PATHFINDER spacecraft. It's launch and operational configuration are identical.

The Pathfinder load bearing structure is comprised of four 40 cm x 46.5 cm skeleton plates, with 82.5 cm long corner rails connecting the four corners of each plate. The Pathfinder satellites maintain 3-axis attitude control. Attitude knowledge is provided by two orthogonally mounted star trackers. Attitude actuators include three orthogonally arranged reaction wheels and three orthogonal magnetorquers.

Total satellite mass at launch, including all propellants and fluids: 45.62 kg.

Dry mass of satellites at launch, excluding solid rocket motor propellants: 41.82 kg

Description of all propulsion systems (cold gas, mono-propellant, bi-propellant, electric, nuclear):

Pathfinder-1 contains a single propulsion system with a single valve and a single thruster. This system uses electrically warmed butane as the working fluid. Butane is stored at saturation conditions

(normally 1 to 100 psi) within two interconnected tanks. The butane is warmed to several hundred degrees Celsius via an electrically heated aluminum block just before exiting the nozzle.

Identification, including mass and pressure, of all fluids (liquids and gases) planned to be on board and a description of the fluid loading plan or strategies, excluding fluids in sealed heat pipes: 3.8 kg of butane at saturation conditions not to exceed 100 psia

Fluids in Pressurized Batteries: None. Pathfinder uses two unpressurized standard COTS Lithium-Ion battery cells. Each cell has a height of 28mm, a width of 76mm, a length of 140mm, and a mass of 890 grams.

Description of attitude control system and indication of the normal attitude of the spacecraft with respect to the velocity vector:

The long axis of the Pathfinder spacecraft can be oriented parallel to the nadir vector during imaging, but the satellite will typically be oriented in a sun-pointing attitude. For the purposes of orbital debris assessment, the worst-case (smallest) cross-sectional area is used, meaning that the 41 cm x 47.5 cm face of the spacecraft is in the velocity direction. This results in a cross-section area of 0.1947 m^2. Using the DAS software, the cross-sectional area during random tumbling is 0.5223 m^2, and the cross-sectional area during narid pointing ("long" side of the spacecraft in the velocity direction) is 0.3931 m^2.

Description of any range safety or other pyrotechnic devices: No pyrotechnic devices are used.

Description of the electrical generation and storage system: Standard COTS Lithium-Ion battery cells are charged before payload integration and provide electrical energy during the mission. The cells are recharged by solar cells mounted on the solar arrays. The battery cell protection circuit manages the charging cycle.

Identification of any other sources of stored energy not noted above: None.

Identification of any radioactive materials on board: None**.**

ODAR Section 3: Assessment of Spacecraft Debris Released during Normal Operations

Identification of any object (>1 mm) expected to be released from the spacecraft any time after launch, including object dimensions, mass, and material: There are no intentional releases.

Rationale/necessity for release of each object: N/A.

Time of release of each object, relative to launch time: N/A.

Release velocity of each object with respect to spacecraft: N/A.

Expected orbital parameters (apogee, perigee, and inclination) of each object after release: N/A.

Calculated orbital lifetime of each object, including time spent in Low Earth Orbit (LEO):

N/A.

Assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2 (per DAS v2.0.2)

4.3-1, Mission Related Debris Passing Through LEO: COMPLIANT

4.3-2, Mission Related Debris Passing Near GEO: COMPLIANT

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

Potential causes of spacecraft breakup during deployment and mission operations:

There is no credible scenario that would result in spacecraft breakup during normal deployment and operations.

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

In-mission failure of a battery cell protection circuit could lead to a short circuit resulting in overheating and a very remote possibility of battery cell explosion. The battery safety systems discussed in the FMEA (see requirement 4.4-1 below) describe the combined faults that must occur for any of seven (7) independent, mutually exclusive failure modes to lead to explosion.

In addition to the battery protection mentioned about, the Pathfinder battery unit features two thermal switches which completely isolate the battery electrically if the temperature gets too high.

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

There are no planned breakups.

List of components which shall be passivated at End of Mission (EOM) including method of passivation and amount which cannot be passivated:

The butane propulsion system shall be passivated at the end of mission by operating the system to propellant depletion in a perigee lowering maneuver. However, it is expected that all propellant will have already been depleted before the end of the operational mission.

Rationale for all items which are required to be passivated, but cannot be due to their design:

Pathfinder battery charge circuits include overcharge protection and a parallel design to limit the risk of battery failure. However, in the unlikely event that a battery cell does explosively rupture, the small size, mass, and potential energy, of these small batteries is such that while the spacecraft could be expected to vent gases, most debris from the battery rupture should be contained within the vessel due to the lack of penetration

energy.

Assessment of spacecraft compliance with Requirements 4.4-1 through 4.4-4:

***Requirement 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:

For each spacecraft and launch vehicle orbital stage employed for a mission, the program or project shall demonstrate, via failure mode and effects analyses or equivalent analyses, that the integrated probability of explosion for all credible failure modes of each spacecraft and launch vehicle is less than 0.001 (excluding small particle impacts) (Requirement 56449).

Compliance statement:

Required Probability: 0.001.

Expected probability: 0.000.

Supporting Rationale and FMEA details:

Battery explosion:

Effect: All failure modes below might theoretically result in battery explosion with the possibility of orbital debris generation. However, in the unlikely event that a battery cell does explosively rupture, the small size, mass, and potential energy, of the selected COTS batteries is such that while the spacecraft could be expected to vent gases, most debris from the battery rupture should be contained within the vessel due to the lack of penetration energy.
Probability: Extremely Low. It is believed to be a much less than 0.1% probability that multiple independent (not common mode) faults must occur for each failure mode to cause the ultimate effect (explosion).

Failure mode 1: Internal short circuit.

Mitigation 1: Qualification and acceptance shock, vibration, thermal cycling, and vacuum tests followed by maximum system rate-limited charge and discharge to prove that no internal short circuit sensitivity exists.

Combined faults required for realized failure: Environmental testing **AND** functional charge/discharge tests must both be ineffective in discovery of the failure mode.

Failure Mode 2: Internal thermal rise due to high load discharge rate.

Mitigation 2: Cells were tested in lab for high load discharge rates in a variety of flight-like configurations to determine like likelihood and impact of an out-of-

control thermal rise in the cell. Cells were also tested in a hot environment to test the upper limit of the cells capability. No failures were seen.

*Combined faults required for realized failure: S*pacecraft thermal design must be incorrect **AND** external over-current detection and disconnect function must fail to enable this failure mode.

Failure Mode 3: Excessive discharge rate or short circuit due to external device failure or terminal contact with conductors not at battery voltage levels (due to abrasion or inadequate proximity separation).

Mitigation 3: This failure mode is negated by a) qualification-tested short circuit protection on each external circuit, b) design of battery packs and insulators such that no contact with nearby board traces is possible without being caused by some other mechanical failure, c) obviation of such other mechanical failures by proto-qualification and acceptance environmental tests (shock, vibration, thermal cycling, and thermal-vacuum tests).

Combined faults required for realized failure: An external load must fail/short-circuit **AND** external over-current detection and disconnect function failure must all occur to enable this failure mode.

Failure Mode 4: Inoperable vents.

Mitigation 4: Battery vents are not inhibited by the battery holder design or the spacecraft.

Combined effects required for realized failure: The final assembler fails to install proper venting.

Failure Mode 5: Crushing.

Mitigation 5: This mode is negated by spacecraft design. There are no moving parts in the proximity of the batteries.

Combined faults required for realized failure: A catastrophic failure must occur in an external system **AND** the failure must cause a collision sufficient to crush the batteries leading to an internal short circuit **AND** the satellite must be in a naturally sustained orbit at the time the crushing occurs.

Failure Mode 6: Low level current leakage or short-circuit through battery pack case or due to moisture-based degradation of insulators.

Mitigation 6: These modes are negated by a) battery holder/case design made of non-conductive plastic, and b) operation in vacuum such that no moisture can

affect insulators.

Combined faults required for realized failure: Abrasion or piercing failure of circuit board coating or wire insulators **AND** dislocation of battery packs **AND** failure of battery terminal insulators **AND** failure to detect such failure modes in environmental tests must occur to result in this failure mode.

Failure Mode 7: Excess temperatures due to orbital environment and high discharge combined.

Mitigation 7: The spacecraft thermal design will negate this possibility. Thermal rise has been analyzed in combination with space environment temperatures showing that batteries do not exceed normal allowable operating temperatures which are well below temperatures of concern for explosions.

Combined faults required for realized failure: Thermal analysis **AND** thermal design **AND** mission simulations in thermal-vacuum chamber testing **AND** over-current monitoring and control must all fail for this failure mode to occur.

Requirement 4.4-2: Design for passivation after completion of mission operations while in orbit about Earth or the Moon:

Design of all spacecraft and launch vehicle orbital stages shall include the ability to deplete all onboard sources of stored energy and disconnect all energy generation sources when they are no longer required for mission operations or postmission disposal or control to a level which cannot cause an explosion or deflagration large enough to release orbital debris or break up the spacecraft (Requirement 56450).

Compliance statement:
Pathfinder battery charge circuits include overcharge protection and a parallel design to limit the risk of battery failure. However, in the unlikely event that a battery cell does explosively rupture, the small size, mass, and potential energy, of these small batteries is such that while the spacecraft could be expected to vent gases, most debris from the battery rupture should be contained within the vessel due to the lack of penetration energy.

Requirement 4.4-3. Limiting the long-term risk to other space systems from planned breakups:

Compliance statement:
This requirement is not applicable. There are no planned breakups.

Requirement 4.4-4: Limiting the short-term risk to other space systems from planned breakups:

Compliance statement:
This requirement is not applicable. There are no planned breakups.

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

Assessment of spacecraft compliance with Requirements 4.5-1 and 4.5-2 (per DAS v2.0.2, and calculation methods provided in NASA-STD-8719.14, section 4.5.4):

Requirement 4.5-1: Limiting debris generated by collisions with large objects when operating in Earth orbit:
For each spacecraft and launch vehicle orbital stage in or passing through LEO, the program or project shall demonstrate that, during the orbital lifetime of each spacecraft and orbital stage, the probability of accidental collision with space objects larger than 10 cm in diameter is less than 0.001 (Requirement 56506).

Large Object Impact and Debris Generation Probability:

Collision Probability: 0.00001; COMPLIANT.

Requirement 4.5-2: Limiting debris generated by collisions with small objects when operating in Earth or lunar orbit**:**
For each spacecraft, the program or project shall demonstrate that, during the mission of the spacecraft, the probability of accidental collision with orbital debris and meteoroids sufficient to prevent compliance with the applicable postmission disposal requirements is less than 0.01 (Requirement 56507).

Small Object Impact and Debris Generation Probability:
Collision Probability: 0.009856; COMPLIANT.

Identification of all systems or components required to accomplish any postmission disposal operation, including passivation and maneuvering:

An orbit change following deployment from the launch vehicle is required to accomplish post-mission disposal. The satellite's propulsion system will be used to lower the orbit from 670 x 670 km to 485 x 670 km. From this orbit, the satellite orbit will naturally decay such that the satellite burns up in Earth's atmosphere in 20 years.

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

6.1 Description of spacecraft disposal option selected: After completing its planned operations, the satellite will deorbit naturally by atmospheric re-entry. At the end of the Pathfinder-1's operational life (i.e. at EOM) the attitude control system will stop counteracting the aerodynamic disturbance

torques and will rotate the satellite into the maximum drag configuration. This will result in Pathfinder gradually assuming a dynamically stable configuration. For atmospheric drag / re-entry calculations in DAS, the minimum plausible cross-section drag area of 41 x 47.5 cm was assumed (smallest spacecraft side facing the velocity direction). This is conservative because it represents the minimum cross section possible with the satellite in any orientation, ignores protuberances, and ignores gravity gradient, ignores solar pressure torques, and ignores the high-drag orientation set at EOM.

6.2 Plan for any spacecraft maneuvers required to accomplish postmission disposal:

No maneuvers are required following normal operations. During operations, however, an orbit lowering maneuver is required. This will be completed as early in the mission as practical after spacecraft subsystems go through checkout procedures.

6.3 Calculation of area-to-mass ratio after postmission disposal, if the controlled reentry option is not selected:

Spacecraft Mass: 41.82 km

Cross-sectional Area: 0.1947 m^2

Area to mass ratio: 0.0047 m^2/kg

6.4 Assessment of spacecraft compliance with Requirements 4.6-1 through 4.6-5 (per DAS v 2.0.2 and NASA-STD-8719.14 section):

Requirement 4.6-1: Disposal for space structures passing through LEO:
A spacecraft or orbital stage with a perigee altitude below 2000 km shall be disposed of by one of three methods:
(Requirement 56557)
a. Atmospheric reentry option:

- *Leave the space structure in an orbit in which natural forces will lead to atmospheric reentry within 25 years after the completion of mission but no more than 30 years after launch; or*
- *Maneuver the space structure into a controlled de-orbit trajectory as soon as practical after completion of mission.*

b. Storage orbit option: Maneuver the space structure into an orbit with perigee altitude greater than 2000 km and apogee less than GEO - 500 km.
c. Direct retrieval: Retrieve the space structure and remove it from orbit within 10 years after completion of mission.

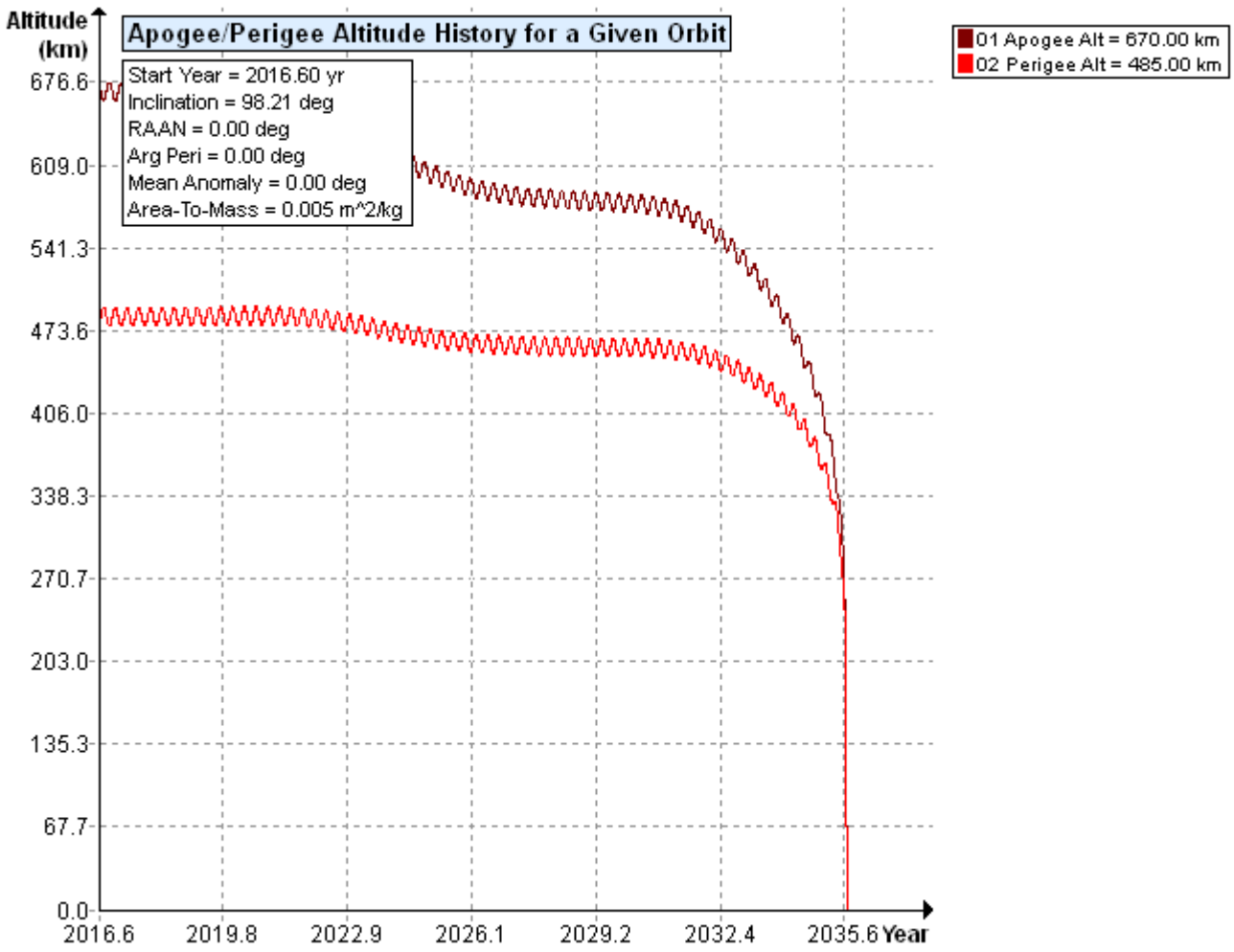

Figure 2 Pathfinder-1 orbit history with apogee (brown) & perigee (red)

Analysis: The Pathfinder-1 satellite reentry is COMPLIANT using method "a".

Satellite Name	Pathfinder-1
BOL Orbit (Drop off)	670 x 670 km
Operational Orbit	670 x 485 km
EOM Orbit	670 x 485 km
Total Lifetime	23 years
Post-ops Life	20 years

Requirement 4.6-2. Disposal for space structures near GEO.

Analysis: Not applicable.

Requirement 4.6-3. Disposal for space structures between LEO and GEO.

Analysis: Not applicable.

Requirement 4.6-4. Reliability of Postmission Disposal Operations

Analysis: The minimum drag configuration is the aerodynamically stable state, and provides the worst-case re-entry time. This minimum drag configuration was assumed for atmospheric re-entry analysis.

ODAR Section 7: Assessment of Spacecraft Reentry Hazards

Assessment of spacecraft compliance with Requirement 4.7-1:

> ***Requirement 4.7-1:*** Limit the risk of human casualty:
> *The potential for human casualty is assumed for any object with an impacting kinetic energy in excess of 15 joules:*
> *a) For uncontrolled reentry, the risk of human casualty from surviving debris shall not exceed 0.0001 (1:10,000) (Requirement 56626).*

Summary Analysis Results: DAS v2.0.2 reports that Pathfinder-1 is compliant with the requirement. According to DAS calculations, there is a low probability that some[1] spacecraft components (primary mirror, a machined disk of Invar, and machined blocks of aluminum) may reach the ground (see DAS input data below for input parameters). However, the DAS software does not currently allow explicit modeling of a the specific geometries for these components, so these numbers are expected to be larger than anticipated due to conservatism in the inputs provided to DAS. Total human casualty probability is reported by the DAS software as **1:29,000** for Pathfinder-1. This is expected to represent the absolute maximum casualty risk, as calculated with DAS's limited modeling capability.

Analysis (per DAS v2.0.2):

```
03 05 2016; 14:05:18PM  DAS Application Started
03 05 2016; 14:05:19PM  Opened Project Z:\Orbital Debris assessment\SCOUT_fromPSLV
PF1 summer 2016 launch\
03 05 2016; 14:05:27PM  Processing Requirement 4.3-1: Return Status :  Not Run

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

=============== End of Requirement 4.3-1 ===============
03 05 2016; 14:05:28PM  Processing Requirement 4.3-2: Return Status : Passed

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

=============== End of Requirement 4.3-2 ===============
03 05 2016; 14:05:29PM  Requirement 4.4-3:  Compliant

=============== End of Requirement 4.4-3 ===============
03 05 2016; 14:05:36PM  Processing Requirement 4.5-1: Return Status :  Passed

==============
```

[1] Other components that were modeled (i.e. wire harnesses, PM struts, shim, etc.) are not likely to survive reentry due to the inability to accurately model these with sufficient fidelity within the limitations imposed by DAS. Even with these components accounted for, Pathfinder-1 is still compliant with this requirement.

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

**INPUT**

      Space Structure Name = SCOUTv1.001
      Space Structure Type = Payload
      Perigee Altitude = 485.000000 (km)
      Apogee Altitude = 670.000000 (km)
      Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass Ratio = 0.004700 (m^2/kg)
      Start Year = 2016.600000 (yr)
      Initial Mass = 45.620000 (kg)
      Final Mass = 41.820000 (kg)
      Duration = 3.000000 (yr)
      Station-Kept = True
      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 = 0.000008
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range
      Status = Pass

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

=============== End of Requirement 4.5-1 ===============
03 05 2016; 14:07:57PM  Requirement 4.5-2:  Compliant

=================================================
Spacecraft = SCOUTv1.001
Critical Surface = CORTEX+X
=================================================

**INPUT**

      Apogee Altitude = 670.000000 (km)
      Perigee Altitude = 485.000000 (km)
      Orbital Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004700 (m^2/kg)
      Initial Mass = 41.820000 (kg)
      Final Mass = 41.820000 (kg)
```

```
      Station Kept = Yes
      Start Year = 2016.600000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 0.885000 (g/cm^2)
      CS Surface Area = 0.020000 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = No
      Outer Wall 1   Density: 0.433000 (g/cm^2)  Separation: 0.400000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.002590
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

================================================
Spacecraft = SCOUTv1.001
Critical Surface = CORTEX+Y
================================================

**INPUT**

      Apogee Altitude = 670.000000 (km)
      Perigee Altitude = 485.000000 (km)
      Orbital Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004700 (m^2/kg)
      Initial Mass = 41.820000 (kg)
      Final Mass = 41.820000 (kg)
      Station Kept = Yes
      Start Year = 2016.600000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 0.885000 (g/cm^2)
      CS Surface Area = 0.020000 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = No
      Outer Wall 1   Density: 0.433000 (g/cm^2)  Separation: 1.800000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.000125
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

================================================
Spacecraft = SCOUTv1.001
Critical Surface = Battery+X
================================================

**INPUT**
```

```
      Apogee Altitude = 670.000000 (km)
      Perigee Altitude = 485.000000 (km)
      Orbital Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004700 (m^2/kg)
      Initial Mass = 41.820000 (kg)
      Final Mass = 41.820000 (kg)
      Station Kept = Yes
      Start Year = 2016.600000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 0.658000 (g/cm^2)
      CS Surface Area = 0.012000 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = No
      Outer Wall 1   Density: 0.433000 (g/cm^2)  Separation: 1.600000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.000141
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

================================================
Spacecraft = SCOUTv1.001
Critical Surface = Battery-Y
================================================

**INPUT**

      Apogee Altitude = 670.000000 (km)
      Perigee Altitude = 485.000000 (km)
      Orbital Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004700 (m^2/kg)
      Initial Mass = 41.820000 (kg)
      Final Mass = 41.820000 (kg)
      Station Kept = Yes
      Start Year = 2016.600000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 0.658000 (g/cm^2)
      CS Surface Area = 0.007000 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = No
      Outer Wall 1   Density: 0.100000 (g/cm^2)  Separation: 3.100000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.000194
      Returned Error Message: Normal Processing
```

```
      Date Range Error Message: Normal Date Range

================================================
Spacecraft = SCOUTv1.001
Critical Surface = Tank+Y
================================================

**INPUT**

      Apogee Altitude = 670.000000 (km)
      Perigee Altitude = 485.000000 (km)
      Orbital Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004700 (m^2/kg)
      Initial Mass = 41.820000 (kg)
      Final Mass = 41.820000 (kg)
      Station Kept = Yes
      Start Year = 2016.600000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 1.080000 (g/cm^2)
      CS Surface Area = 0.038720 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = Yes
      Outer Wall 1   Density: 0.433000 (g/cm^2)  Separation: 7.300000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.000375
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

================================================
Spacecraft = SCOUTv1.001
Critical Surface = Tank-Y
================================================

**INPUT**

      Apogee Altitude = 670.000000 (km)
      Perigee Altitude = 485.000000 (km)
      Orbital Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004700 (m^2/kg)
      Initial Mass = 41.820000 (kg)
      Final Mass = 41.820000 (kg)
      Station Kept = Yes
      Start Year = 2016.600000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 1.080000 (g/cm^2)
```

```
      CS Surface Area = 0.038720 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = Yes
      Outer Wall 1   Density: 0.433000 (g/cm^2)  Separation: 7.300000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.000375
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

================================================
Spacecraft = SCOUTv1.001
Critical Surface = Tank+X_sect1
================================================

**INPUT**

      Apogee Altitude = 670.000000 (km)
      Perigee Altitude = 485.000000 (km)
      Orbital Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004700 (m^2/kg)
      Initial Mass = 41.820000 (kg)
      Final Mass = 41.820000 (kg)
      Station Kept = Yes
      Start Year = 2016.600000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 1.080000 (g/cm^2)
      CS Surface Area = 0.004090 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = Yes
      Outer Wall 1   Density: 0.433000 (g/cm^2)  Separation: 0.470000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.001703
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

================================================
Spacecraft = SCOUTv1.001
Critical Surface = Tank+X_sect2
================================================

**INPUT**

      Apogee Altitude = 670.000000 (km)
      Perigee Altitude = 485.000000 (km)
      Orbital Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
```

```
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004700 (m^2/kg)
      Initial Mass = 41.820000 (kg)
      Final Mass = 41.820000 (kg)
      Station Kept = Yes
      Start Year = 2016.600000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 1.080000 (g/cm^2)
      CS Surface Area = 0.008180 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = Yes
      Outer Wall 1   Density: 0.433000 (g/cm^2)  Separation: 0.850000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.001025
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

================================================
Spacecraft = SCOUTv1.001
Critical Surface = Tank+X_sect3
================================================

**INPUT**

      Apogee Altitude = 670.000000 (km)
      Perigee Altitude = 485.000000 (km)
      Orbital Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004700 (m^2/kg)
      Initial Mass = 41.820000 (kg)
      Final Mass = 41.820000 (kg)
      Station Kept = Yes
      Start Year = 2016.600000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 1.080000 (g/cm^2)
      CS Surface Area = 0.008180 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = Yes
      Outer Wall 1   Density: 0.433000 (g/cm^2)  Separation: 1.970000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.000164
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

================================================
Spacecraft = SCOUTv1.001
Critical Surface = Tank+X_sect4
```

```
================================================

**INPUT**

      Apogee Altitude = 670.000000 (km)
      Perigee Altitude = 485.000000 (km)
      Orbital Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004700 (m^2/kg)
      Initial Mass = 41.820000 (kg)
      Final Mass = 41.820000 (kg)
      Station Kept = Yes
      Start Year = 2016.600000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 1.080000 (g/cm^2)
      CS Surface Area = 0.008180 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = Yes
      Outer Wall 1   Density: 0.433000 (g/cm^2)  Separation: 3.710000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.000081
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

================================================
Spacecraft = SCOUTv1.001
Critical Surface = Tank+X_sect5
================================================

**INPUT**

      Apogee Altitude = 670.000000 (km)
      Perigee Altitude = 485.000000 (km)
      Orbital Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004700 (m^2/kg)
      Initial Mass = 41.820000 (kg)
      Final Mass = 41.820000 (kg)
      Station Kept = Yes
      Start Year = 2016.600000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 1.080000 (g/cm^2)
      CS Surface Area = 0.008180 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = Yes
      Outer Wall 1   Density: 0.433000 (g/cm^2)  Separation: 5.890000 (cm)
```

```
**OUTPUT**

      Probabilty of Penitration = 0.000079
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

================================================
Spacecraft = SCOUTv1.001
Critical Surface = Tank-X_sect1
================================================

**INPUT**

      Apogee Altitude = 670.000000 (km)
      Perigee Altitude = 485.000000 (km)
      Orbital Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004700 (m^2/kg)
      Initial Mass = 41.820000 (kg)
      Final Mass = 41.820000 (kg)
      Station Kept = Yes
      Start Year = 2016.600000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 1.080000 (g/cm^2)
      CS Surface Area = 0.004090 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = Yes
      Outer Wall 1   Density: 0.433000 (g/cm^2)  Separation: 0.470000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.001703
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

================================================
Spacecraft = SCOUTv1.001
Critical Surface = Tank-X_sect2
================================================

**INPUT**

      Apogee Altitude = 670.000000 (km)
      Perigee Altitude = 485.000000 (km)
      Orbital Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004700 (m^2/kg)
      Initial Mass = 41.820000 (kg)
      Final Mass = 41.820000 (kg)
      Station Kept = Yes
```

```
      Start Year = 2016.600000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 1.080000 (g/cm^2)
      CS Surface Area = 0.008180 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = Yes
      Outer Wall 1   Density: 0.433000 (g/cm^2)  Separation: 0.850000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.001025
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

================================================
Spacecraft = SCOUTv1.001
Critical Surface = Tank-X_sect3
================================================

**INPUT**

      Apogee Altitude = 670.000000 (km)
      Perigee Altitude = 485.000000 (km)
      Orbital Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004700 (m^2/kg)
      Initial Mass = 41.820000 (kg)
      Final Mass = 41.820000 (kg)
      Station Kept = Yes
      Start Year = 2016.600000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 1.080000 (g/cm^2)
      CS Surface Area = 0.008180 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = Yes
      Outer Wall 1   Density: 0.433000 (g/cm^2)  Separation: 1.970000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.000164
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

================================================
Spacecraft = SCOUTv1.001
Critical Surface = Tank-X_sect4
================================================

**INPUT**

      Apogee Altitude = 670.000000 (km)
```

```
      Perigee Altitude = 485.000000 (km)
      Orbital Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004700 (m^2/kg)
      Initial Mass = 41.820000 (kg)
      Final Mass = 41.820000 (kg)
      Station Kept = Yes
      Start Year = 2016.600000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 1.080000 (g/cm^2)
      CS Surface Area = 0.008180 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = Yes
      Outer Wall 1   Density: 0.433000 (g/cm^2)  Separation: 3.710000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.000081
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

================================================
Spacecraft = SCOUTv1.001
Critical Surface = Tank-X_sect5
================================================

**INPUT**

      Apogee Altitude = 670.000000 (km)
      Perigee Altitude = 485.000000 (km)
      Orbital Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004700 (m^2/kg)
      Initial Mass = 41.820000 (kg)
      Final Mass = 41.820000 (kg)
      Station Kept = Yes
      Start Year = 2016.600000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 1.080000 (g/cm^2)
      CS Surface Area = 0.008180 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = Yes
      Outer Wall 1   Density: 0.433000 (g/cm^2)  Separation: 5.890000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.000079
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range
```

```
03 05 2016; 14:11:54PM  Processing Requirement 4.6    Return Status :  Passed

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

**INPUT**

      Space Structure Name = SCOUTv1.001
      Space Structure Type = Payload

      Perigee Altitude = 485.000000 (km)
      Apogee Altitude = 670.000000 (km)
      Inclination = 98.210000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Area-To-Mass Ratio = 0.004700 (m^2/kg)
      Start Year = 2016.600000 (yr)
      Initial Mass = 45.620000 (kg)
      Final Mass = 41.820000 (kg)
      Duration = 3.000000 (yr)
      Station Kept = True
      Abandoned = True
      PMD Perigee Altitude = 485.000000 (km)
      PMD Apogee Altitude = 670.000000 (km)
      PMD Inclination = 98.210000 (deg)
      PMD RAAN = 0.000000 (deg)
      PMD Argument of Perigee = 0.000000 (deg)
      PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

      Suggested Perigee Altitude = 485.000000 (km)
      Suggested Apogee Altitude = 670.000000 (km)
      Returned Error Message = Passes LEO reentry orbit criteria.

      Released Year = 2035 (yr)
      Requirement = 61
      Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
03 05 2016; 14:11:58PM  *********Processing Requirement 4.7-1
      Return Status :  Passed

***********INPUT****
 Item Number = 1

name = SCOUTv1.001
quantity = 1
parent = 0
```

```
materialID = 5
type = Box
Aero Mass = 41.820000
Thermal Mass = 41.820000
Diameter/Width = 0.400000
Length = 0.850000
Height = 0.400000

name = Shell
quantity = 1
parent = 1
materialID = 27
type = Cylinder
Aero Mass = 0.300800
Thermal Mass = 0.300800
Diameter/Width = 0.280000
Length = 0.390000

name = SM baffle
quantity = 1
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 0.058100
Thermal Mass = 0.058100
Diameter/Width = 0.074000
Length = 0.046000

name = SM cover
quantity = 1
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 0.064300
Thermal Mass = 0.064300
Diameter/Width = 0.070000
Length = 0.023000

name = PM
quantity = 1
parent = 1
materialID = -1
type = Flat Plate
Aero Mass = 1.036500
Thermal Mass = 1.036500
Diameter/Width = 0.223300
Length = 0.223300

name = PM baffle
quantity = 1
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 0.234800
Thermal Mass = 0.234800
```

```
Diameter/Width = 0.116000
Length = 0.186500

name = SM spider
quantity = 1
parent = 1
materialID = 72
type = Flat Plate
Aero Mass = 0.432300
Thermal Mass = 0.432300
Diameter/Width = 0.100000
Length = 0.100000

name = Shutter Housing
quantity = 1
parent = 1
materialID = 72
type = Box
Aero Mass = 0.784600
Thermal Mass = 0.784600
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.024200

name = AMS upper plate
quantity = 1
parent = 1
materialID = 27
type = Flat Plate
Aero Mass = 0.103000
Thermal Mass = 0.103000
Diameter/Width = 0.270000
Length = 0.270000

name = AMS core structure
quantity = 1
parent = 1
materialID = 7
type = Flat Plate
Aero Mass = 0.090400
Thermal Mass = 0.090400
Diameter/Width = 0.270000
Length = 0.270000

name = AMS lower plate
quantity = 1
parent = 1
materialID = 27
type = Flat Plate
Aero Mass = 0.102900
Thermal Mass = 0.102900
Diameter/Width = 0.270000
Length = 0.270000

name = Lens Tube Shim
```

```
quantity = 1
parent = 1
materialID = 54
type = Flat Plate
Aero Mass = 0.023200
Thermal Mass = 0.023200
Diameter/Width = 0.020000
Length = 0.200000

name = PM Baffle AMS Lock Ring
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.015600
Thermal Mass = 0.015600
Diameter/Width = 0.020000
Length = 0.200000

name = Main PM Mount Flexure
quantity = 3
parent = 1
materialID = 9
type = Flat Plate
Aero Mass = 0.089300
Thermal Mass = 0.089300
Diameter/Width = 0.101000
Length = 0.138000

name = PM struts
quantity = 3
parent = 1
materialID = 72
type = Box
Aero Mass = 0.032900
Thermal Mass = 0.032900
Diameter/Width = 0.030000
Length = 0.030000
Height = 0.010000

name = Camera
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.328000
Thermal Mass = 0.328000
Diameter/Width = 0.060000
Length = 0.060000
Height = 0.045000

name = MLI
quantity = 1
parent = 1
materialID = 44
```

```
type = Cylinder
Aero Mass = 0.293300
Thermal Mass = 0.293300
Diameter/Width = 0.300000
Length = 0.450000

name = Propulsion Deck Base Plate
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 2.987600
Thermal Mass = 2.987600
Diameter/Width = 0.400000
Length = 0.400000

name = Avionics Deck Base Plate
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 2.283700
Thermal Mass = 2.283700
Diameter/Width = 0.400000
Length = 0.400000

name = Optical Bench Base Plate
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 1.459100
Thermal Mass = 1.459100
Diameter/Width = 0.400000
Length = 0.400000

name = Antenna Deck Base Plate
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.812200
Thermal Mass = 0.812200
Diameter/Width = 0.400000
Length = 0.400000

name = Antenna Deck Extension
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.052700
Thermal Mass = 0.052700
Diameter/Width = 0.029000
Length = 0.400000
```

```
name = Corner Rail 1
quantity = 4
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.345800
Thermal Mass = 0.345800
Diameter/Width = 0.045000
Length = 0.820000

name = Side Cross Brace
quantity = 2
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.138700
Thermal Mass = 0.138700
Diameter/Width = 0.035000
Length = 0.450000

name = Center Cross Brace
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.138700
Thermal Mass = 0.138700
Diameter/Width = 0.035000
Length = 0.450000

name = Optical Bench Corner Bracket Assembly
quantity = 4
parent = 1
materialID = 8
type = Box
Aero Mass = 0.036600
Thermal Mass = 0.036600
Diameter/Width = 0.037000
Length = 0.037000
Height = 0.037000

name = Propulsion Deck Corner Bracket Assembly
quantity = 8
parent = 1
materialID = 8
type = Box
Aero Mass = 0.036600
Thermal Mass = 0.036600
Diameter/Width = 0.037000
Length = 0.037000
Height = 0.037000

name = Front Close-out Panel
quantity = 1
```

```
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 1.440000
Thermal Mass = 1.440000
Diameter/Width = 0.350000
Length = 0.355000

name = Side Close-out Panel
quantity = 2
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.623400
Thermal Mass = 0.623400
Diameter/Width = 0.350000
Length = 0.355000

name = Rear Close-out Panel
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.338000
Thermal Mass = 0.338000
Diameter/Width = 0.194000
Length = 0.350000

name = OTA Cover - deployed
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.736500
Thermal Mass = 0.736500
Diameter/Width = 0.358000
Length = 0.382000

name = Lid Hinge
quantity = 2
parent = 1
materialID = 8
type = Box
Aero Mass = 0.044700
Thermal Mass = 0.044700
Diameter/Width = 0.025000
Length = 0.032000
Height = 0.025000

name = Pin Puller
quantity = 1
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 0.031200
```

```
Thermal Mass = 0.031200
Diameter/Width = 0.024000
Length = 0.032000

name = Pin Piller Bracket
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.037800
Thermal Mass = 0.037800
Diameter/Width = 0.022500
Length = 0.100000
Height = 0.015000

name = Fasteners
quantity = 1600
parent = 1
materialID = 54
type = Cylinder
Aero Mass = 0.001250
Thermal Mass = 0.001250
Diameter/Width = 0.006000
Length = 0.020000

name = Cortex
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 2.867500
Thermal Mass = 2.867500
Diameter/Width = 0.151000
Length = 0.161000
Height = 0.106000

name = Reaction Wheels
quantity = 3
parent = 1
materialID = 54
type = Cylinder
Aero Mass = 0.228400
Thermal Mass = 0.228400
Diameter/Width = 0.063000
Length = 0.025400

name = Reaction Wheel Bracket
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.204800
Thermal Mass = 0.204800
Diameter/Width = 0.075000
Length = 0.090000
```

```
Height = 0.014000

name = Torque Rods
quantity = 3
parent = 1
materialID = 54
type = Cylinder
Aero Mass = 0.737000
Thermal Mass = 0.737000
Diameter/Width = 0.034000
Length = 0.120000

name = TQ-15 Bracket
quantity = 6
parent = 1
materialID = 8
type = Box
Aero Mass = 0.108900
Thermal Mass = 0.108900
Diameter/Width = 0.034000
Length = 0.060000
Height = 0.020000

name = Rate Sensor / Bracket Assembly
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.373900
Thermal Mass = 0.373900
Diameter/Width = 0.060000
Length = 0.080000
Height = 0.060000

name = Star Tracker / Bracket Assembly
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.153000
Thermal Mass = 1.153000
Diameter/Width = 0.118000
Length = 0.268000
Height = 0.108000

name = GPS Card / Enclosure Assembly
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.245100
Thermal Mass = 0.245100
Diameter/Width = 0.071000
Length = 0.136000
Height = 0.023000
```

```
name = GPS Antenna Assembly
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.043400
Thermal Mass = 0.043400
Diameter/Width = 0.030000
Length = 0.030000
Height = 0.025400

name = Solar Panel 1
quantity = 6
parent = 1
materialID = 50
type = Flat Plate
Aero Mass = 0.319100
Thermal Mass = 0.319100
Diameter/Width = 0.180000
Length = 0.340000

name = Battery
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 2.196200
Thermal Mass = 2.196200
Diameter/Width = 0.108000
Length = 0.178000
Height = 0.065000

name = Harnesses
quantity = 1
parent = 1
materialID = 19
type = Cylinder
Aero Mass = 1.524900
Thermal Mass = 1.524900
Diameter/Width = 0.005100
Length = 8.500000

name = Tank
quantity = 2
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 1.322900
Thermal Mass = 1.322900
Diameter/Width = 0.156000
Length = 0.238000

name = HEX
quantity = 1
```

```
parent = 1
materialID = 5
type = Box
Aero Mass = 0.186400
Thermal Mass = 0.186400
Diameter/Width = 0.054000
Length = 0.114000
Height = 0.023000

name = Propulsion Manifold Assembly
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.296700
Thermal Mass = 0.296700
Diameter/Width = 0.065000
Length = 0.075000
Height = 0.030000

name = Tubing Run 1
quantity = 4
parent = 1
materialID = 54
type = Cylinder
Aero Mass = 0.015500
Thermal Mass = 0.015500
Diameter/Width = 0.002000
Length = 0.800000

name = Tube Fitting
quantity = 8
parent = 1
materialID = 54
type = Sphere
Aero Mass = 0.034600
Thermal Mass = 0.034600
Diameter/Width = 0.100000

name = SM spider fitting
quantity = 9
parent = 1
materialID = 5
type = Cylinder
Aero Mass = 0.052000
Thermal Mass = 0.052000
Diameter/Width = 0.041000
Length = 0.015000

name = HEX Insulation
quantity = 1
parent = 1
materialID = 76
type = Flat Plate
Aero Mass = 0.020900
```

```
Thermal Mass = 0.020900
Diameter/Width = 0.054000
Length = 0.114000

name = HEX Bracket
quantity = 1
parent = 1
materialID = 66
type = Flat Plate
Aero Mass = 0.035000
Thermal Mass = 0.035000
Diameter/Width = 0.089000
Length = 0.143000

name = UHF Antenna Assembly
quantity = 1
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 0.067100
Thermal Mass = 0.067100
Diameter/Width = 0.025200
Length = 0.050000

name = MLB flyaway portion
quantity = 1
parent = 1
materialID = 9
type = Box
Aero Mass = 0.473700
Thermal Mass = 0.473700
Diameter/Width = 0.184000
Length = 0.185000
Height = 0.005000

name = Antenna Deck Angle Brackets
quantity = 8
parent = 1
materialID = 8
type = Box
Aero Mass = 0.007400
Thermal Mass = 0.007400
Diameter/Width = 0.020000
Length = 0.130000
Height = 0.001100

name = CORTEX thermal pad
quantity = 1
parent = 1
materialID = -4
type = Flat Plate
Aero Mass = 0.068400
Thermal Mass = 0.068400
Diameter/Width = 0.151000
Length = 0.161000
```

```
name = Battery thermal pad
quantity = 1
parent = 1
materialID = -4
type = Flat Plate
Aero Mass = 0.025000
Thermal Mass = 0.025000
Diameter/Width = 0.108000
Length = 0.178000

name = Battery Spacer
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.065800
Thermal Mass = 0.065800
Diameter/Width = 0.013000
Length = 0.178000
Height = 0.011000

name = S-band antenna
quantity = 1
parent = 1
materialID = 5
type = Flat Plate
Aero Mass = 0.083600
Thermal Mass = 0.083600
Diameter/Width = 0.100000
Length = 0.100000

name = S-band antenna bracket
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.055100
Thermal Mass = 0.055100
Diameter/Width = 0.090000
Length = 0.105000

name = S-band radio
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.329000
Thermal Mass = 0.329000
Diameter/Width = 0.080000
Length = 0.130000
Height = 0.024000

name = UHF radio
quantity = 1
```

```
parent = 1
materialID = 5
type = Box
Aero Mass = 0.089200
Thermal Mass = 0.089200
Diameter/Width = 0.070000
Length = 0.080000
Height = 0.017000

name = X-band radio
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 1.100000
Thermal Mass = 1.100000
Diameter/Width = 0.100000
Length = 0.170000
Height = 0.040000

name = X-band thermal pad
quantity = 1
parent = 1
materialID = 27
type = Flat Plate
Aero Mass = 0.009100
Thermal Mass = 0.009100
Diameter/Width = 0.100000
Length = 0.170000

name = X-band antenna
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.253000
Thermal Mass = 0.253000
Diameter/Width = 0.130000
Length = 0.180000
Height = 0.020000

name = X-band antenna bracket
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.096500
Thermal Mass = 0.096500
Diameter/Width = 0.115000
Length = 0.190000

**************OUTPUT****
Item Number = 1

name = SCOUTv1.001
```

```
Demise Altitude = 77.993972
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Shell
Demise Altitude = 77.852183
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = SM baffle
Demise Altitude = 76.692097
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = SM cover
Demise Altitude = 75.900386
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = PM
Demise Altitude = 0.000000
Debris Casualty Area = 0.677823
Impact Kinetic Energy = 352.264130

************************************
name = PM baffle
Demise Altitude = 76.595066
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = SM spider
Demise Altitude = 0.000000
Debris Casualty Area = 0.490000
Impact Kinetic Energy = 306.367584

************************************
name = Shutter Housing
Demise Altitude = 0.000000
Debris Casualty Area = 0.460774
Impact Kinetic Energy = 943.198425

************************************
name = AMS upper plate
Demise Altitude = 77.899543
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = AMS core structure
Demise Altitude = 77.556847
```

```
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = AMS lower plate
Demise Altitude = 77.899543
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Lens Tube Shim
Demise Altitude = 0.000000
Debris Casualty Area = 0.439895
Impact Kinetic Energy = 2.195970

************************************
name = PM Baffle AMS Lock Ring
Demise Altitude = 77.440621
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Main PM Mount Flexure
Demise Altitude = 76.787668
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = PM struts
Demise Altitude = 0.000000
Debris Casualty Area = 1.169982
Impact Kinetic Energy = 16.327818

************************************
name = Camera
Demise Altitude = 70.822050
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = MLI
Demise Altitude = 77.885980
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Propulsion Deck Base Plate
Demise Altitude = 68.463480
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Avionics Deck Base Plate
Demise Altitude = 70.745988
Debris Casualty Area = 0.000000
```

```
Impact Kinetic Energy = 0.000000

************************************
name = Optical Bench Base Plate
Demise Altitude = 73.426621
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Antenna Deck Base Plate
Demise Altitude = 75.510761
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Antenna Deck Extension
Demise Altitude = 77.249582
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Corner Rail 1
Demise Altitude = 76.162168
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Side Cross Brace
Demise Altitude = 76.449824
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Center Cross Brace
Demise Altitude = 76.449824
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Optical Bench Corner Bracket Assembly
Demise Altitude = 76.406769
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Propulsion Deck Corner Bracket Assembly
Demise Altitude = 76.406769
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Front Close-out Panel
Demise Altitude = 72.821363
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
************************************
name = Side Close-out Panel
Demise Altitude = 75.812277
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Rear Close-out Panel
Demise Altitude = 76.511308
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = OTA Cover - deployed
Demise Altitude = 75.588511
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Lid Hinge
Demise Altitude = 75.091269
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Pin Puller
Demise Altitude = 75.494347
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Pin Piller Bracket
Demise Altitude = 76.665965
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Fasteners
Demise Altitude = 77.149926
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Cortex
Demise Altitude = 64.924218
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Reaction Wheels
Demise Altitude = 67.376089
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
************************************
name = Reaction Wheel Bracket
Demise Altitude = 73.787332
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Torque Rods
Demise Altitude = 60.962565
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = TQ-15 Bracket
Demise Altitude = 74.047652
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Rate Sensor / Bracket Assembly
Demise Altitude = 72.849785
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Star Tracker / Bracket Assembly
Demise Altitude = 74.102644
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = GPS Card / Enclosure Assembly
Demise Altitude = 74.808777
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = GPS Antenna Assembly
Demise Altitude = 75.150613
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Solar Panel 1
Demise Altitude = 77.558902
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Battery
Demise Altitude = 66.202394
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
```

```
name = Harnesses
Demise Altitude = 76.721176
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Tank
Demise Altitude = 72.997371
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = HEX
Demise Altitude = 74.602254
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Propulsion Manifold Assembly
Demise Altitude = 72.108324
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Tubing Run 1
Demise Altitude = 77.351582
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Tube Fitting
Demise Altitude = 0.000000
Debris Casualty Area = 3.793610
Impact Kinetic Energy = 2.745901

************************************
name = SM spider fitting
Demise Altitude = 73.928754
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = HEX Insulation
Demise Altitude = 77.891996
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = HEX Bracket
Demise Altitude = 0.000000
Debris Casualty Area = 0.508104
Impact Kinetic Energy = 1.570260

************************************
name = UHF Antenna Assembly
```

```
Demise Altitude = 74.381230
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = MLB flyaway portion
Demise Altitude = 74.455652
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Antenna Deck Angle Brackets
Demise Altitude = 77.616488
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = CORTEX thermal pad
Demise Altitude = 77.831402
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Battery thermal pad
Demise Altitude = 77.933074
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Battery Spacer
Demise Altitude = 76.216925
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = S-band antenna
Demise Altitude = 76.169332
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = S-band antenna bracket
Demise Altitude = 76.874871
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = S-band radio
Demise Altitude = 73.562105
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = UHF radio
Demise Altitude = 75.751918
```

```
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = X-band radio
Demise Altitude = 69.238191
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = X-band thermal pad
Demise Altitude = 77.973652
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = X-band antenna
Demise Altitude = 75.899566
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = X-band antenna bracket
Demise Altitude = 77.034676
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************

=============== End of Requirement 4.7-1 ===============
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Requirements 4.7-1b, and 4.7-1c below are non-applicable requirements because Pathfinder does not use controlled reentry.

4.7-1, b) **NOT APPLICABLE.** For controlled reentry, the selected trajectory shall ensure that no surviving debris impact with a kinetic energy greater than 15 joules is closer than 370 km from foreign landmasses, or is within 50 km from the continental U.S., territories of the U.S., and the permanent ice pack of Antarctica (Requirement 56627).

4.7-1 c) **NOT APPLICABLE.** For controlled reentries, the product of the probability of failure of the reentry burn (from Requirement 4.6-4.b) and the risk of human casualty assuming uncontrolled reentry shall not exceed 0.0001 (1:10,000) (Requirement 56628).

ODAR Section 8: Assessment for Tether Missions

Not applicable. There are no tethers on the Pathfinder satellites.

END of ODAR for Pathfinder-1