BlackSky's Global-1 Satellite Orbital Debris Assessment Report (ODAR)

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

Report Version: 4, September 28, 2017

Revision history:

Version	Date	Author	Description
1	1/4/17	Lang Kenney	Creation of report for Global-1 spacecraft
2	1/20/2017	Lang Kenney	Update of the report to include Global-2,3,4
3	4/26/2017	John Springmann	Modified Global-1 orbit
3a	5/19/17	John Springmann	Reduced to cover Global-1 satellite, only. Technical content otherwise unchanged.
4	9/28/2017	Lang Kenney	Modified Global-1 Launch date

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This document contains no proprietary, ITAR, or export controlled information.

DAS Software Version Used In Analysis: v2.0.2

DAS Solar flux file Used: Released 7 November 2016

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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: Global-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.
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 0.00001
4.5-2	☐	☐	☐	☐	☒	☐	☐	Damage probability < 0.0099
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.

Assessment Report Format:

ODAR Technical Sections Format Requirements:

BlackSky Global, LLC is a US company; this ODAR, for BlackSky Global's Global-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 vehicles ODAR and are not covered here.

All files created from the DAS 2.0.2 software and calculation files are located on Windchill.

Windchill Link (This is a BlackSky Global, LLC internal reference)

ODAR Section 1: Program Management and Mission Overview

Project Manager: John Springmann

Foreign government or space agency participation: none

Schedule of upcoming mission milestones:

Satellite	Flight Readiness Review	Launch
Global-1	February 2018	May-June 2018

Table 1: Mission Milestones

Mission Overview:
Global-1 is an Earth observation satellite. It is a follow-on mission to BlackSky's Pathfinder-1 satellite and is the first in a series of BlackSky satellites. The launch window for Global-1 is May-June 2018. The satellite will be deployed into circular sun-synchronous low-Earth orbit. The altitude of the circular orbit will be between 500 and 550 km. The spacecraft is a secondary payload on the launch, and the exact altitude within the 500-550 km range has not yet been confirmed. 550 km is the altitude used in this report as that is the conservative assumption from an orbital lifetime standpoint. The orbit details used in this report are summarized in Table 3 below.

The planned mission duration for the satellite is 36 months (3 years). 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 (max is 16.5 years including 3 years of operations, as calculated by DAS 2.0.2).

Launch vehicles and launch sites:

Project	Launch Vehicle	Launch location
Global-1	**PSLV**	**Satish Dhawan Space Centre, Sriharikota, India**

Table 2: Launch Vehicle and Launch Site

Mission duration: Maximum Nominal Operations: 36 months (3 years)

Post-Operations Orbit lifetime: See Table 5 in section 6.3

Satellite launch and orbit profile:

Project	Altitude	Inclination	LTDN or LTAN	Comments
Global-1	550 km	97.59°	09:30 LTDN	550 km circular orbit

Table 3: Orbit profile

ODAR Section 2: Spacecraft Description

Physical description of the spacecraft:

Global-1 has a launch mass of 54.38 kg. Basic physical dimensions are 45 cm x 50 cm x 84.5 cm. A CAD model of the spacecraft is shown in Figure 1.

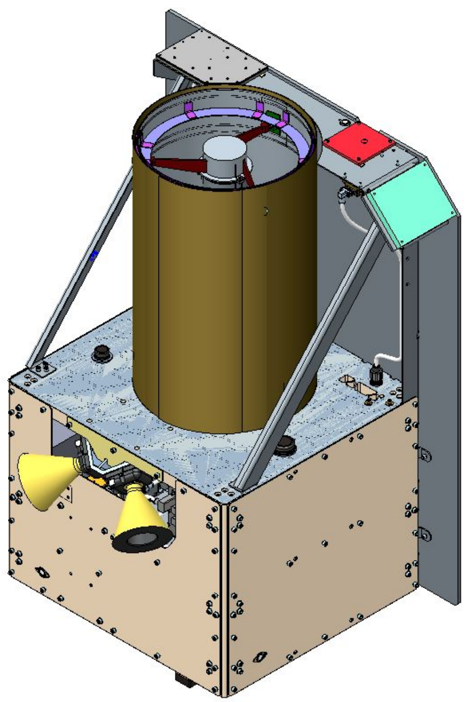

Figure 1. CAD model of the Global-1 spacecraft.

The satellite's load bearing structure is comprised of three 45 cm x 50 cm skeleton deck plates, radiating side plates, and a vertical mounted 66.5cm x 84.5 cm side solar panel connected with struts. The satellite maintains 3-axis attitude control. Attitude knowledge is provided primarily by two orthogonally mounted star trackers. Attitude actuators include four reaction wheels and three orthogonal magnetorquers.

Total satellite mass at launch, including all propellants and fluids: 54.38 kg.

Dry mass of satellites at launch, excluding solid rocket motor propellants: 50.62 kg

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

Global-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. Propulsion is not required to deorbit the satellite, but is part of the satellite to allow for orbit phasing and minor orbit adjustments.

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: 3.76 kg of butane at saturation conditions not to exceed 100psia

Fluids in Pressurized Batteries: None. Global-1 uses two unpressurized standard COTS Lithium-Ion batteries. Each battery has a height of 98mm, a width of 96mm, a length of 176mm, and a mass of 1.4 kg.

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 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 45 cm x 50 cm face of the spacecraft is in the velocity direction. This results in a cross-section area of $0.225m^2$. Using the DAS software, the cross-sectional area during random tumbling is $0.56\ m^2$, and the cross-sectional area during nadir pointing (“long” side of the spacecraft in the velocity direction) is $0.5619\ m^2$.

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 Global-1 battery unit features two temperature sensors which monitor battery cells for high temperatures.

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:

The satellite's 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.

*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:
Global 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:

Satellite	Collision Probability	Compliance status
Global-1	0.00001	COMPLIANT

Table 4: Large Debris Generation

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: not applicable; COMPLIANT.

The satellite orbits decay naturally; no propulsion is required for most-mission disposal. Thus there are no parts of the satellite that are critical to be in compliance with post-mission disposal requirements.

Identification of all systems or components required to accomplish any postmission disposal operation, including passivation and maneuvering:
No systems or components are required. The orbit for Global-1 naturally decays with no maneuvering required.

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 satellites will deorbit naturally by atmospheric re-entry. At the end of the satellite's operational life (i.e. at EOM) the attitude control system will stop counteracting the aerodynamic disturbance torques. This will result in the satellite gradually assuming a dynamically stable configuration. For atmospheric drag / re-entry calculations in DAS, the minimum plausible cross-section drag area of 45 x 50 cm was assumed (smallest spacecraft side facing the velocity direction). This is conservative because it represents the minimum cross section possible and ignores the fact that the satellite may be in other orientations after the end of the mission.

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

No maneuvers are required following normal operations.

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

Spacecraft Mass (EOL): 50.62 kg

Cross-sectional Area: 0.225 m^2

Area to mass ratio: 0.004444883 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.

The analysis of this requirement for each satellite is shown below.

Satellite Name	Operational Orbit	Post-ops Life	Total Lifetime
Global-1	550 km circular	13.5 years	16.5 years

Table 5: Lifetimes

Altitude history versus time was analyzed for Global-1 and is shown below.

Global-1 Altitude history over time:

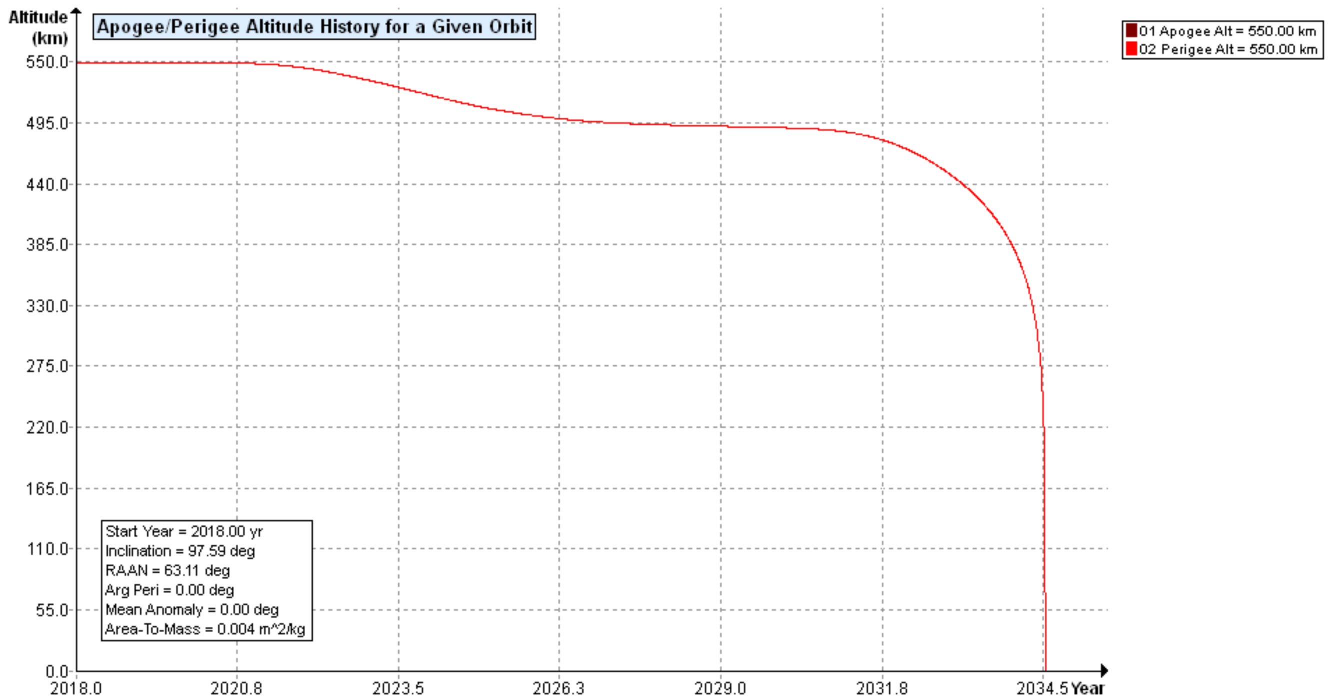

Figure 2: Global-1 Apogee/Perigee Altitude History for a Given Orbit

Analysis: The Global-1 satellite reentry is COMPLIANT using method "a: *Atmospheric reentry option*".

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 Global-1 is compliant with the requirement. The total risk of human casualty for each spacecraft is given in the table below. According to DAS calculations, there is a low probability that some spacecraft components may reach the ground (see DAS input data below for input parameters). However, the DAS software does not currently allow explicit modeling of 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.

Satellite	Risk of Human Casualty	Compliance status
Global-1	1:26,300	COMPLIANT

Table 6. Casualty risk from re-entry debris.

Below is a full output from the DAS software for Global-1.

Analysis (per DAS v2.0.2):

```
09 28 2017; 11:35:49AM  DAS Application Started
09 28 2017; 11:36:44AM  Processing Requirement 4.3-1: Return Status :  Not Run

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

=============== End of Requirement 4.3-1 ===============
09 28 2017; 11:36:46AM  Processing Requirement 4.3-2: Return Status : Passed

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

=============== End of Requirement 4.3-2 ===============
09 28 2017; 11:36:48AM  Requirement 4.4-3:  Compliant

=============== End of Requirement 4.4-3 ===============
09 28 2017; 11:36:52AM  Processing Requirement 4.5-1: Return Status :  Passed

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

**INPUT**

      Space Structure Name = Global-1
```

```
      Space Structure Type = Payload
      Perigee Altitude = 550.000000 (km)
      Apogee Altitude = 550.000000 (km)
      Inclination = 97.590000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass Ratio = 0.004445 (m^2/kg)
      Start Year = 2018.000000 (yr)
      Initial Mass = 58.080000 (kg)
      Final Mass = 54.320000 (kg)
      Duration = 3.000000 (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 = 0.000007
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range
      Status = Pass

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

=============== End of Requirement 4.5-1 ===============
09 28 2017; 11:38:04AM  Requirement 4.5-2:  Compliant

==================================================
Spacecraft = Global-1
Critical Surface = FC+X
==================================================

**INPUT**

      Apogee Altitude = 550.000000 (km)
      Perigee Altitude = 550.000000 (km)
      Orbital Inclination = 97.590000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004445 (m^2/kg)
      Initial Mass = 54.320000 (kg)
      Final Mass = 54.320000 (kg)
      Station Kept = No
      Start Year = 2018.000000 (yr)
      Duration = 3.000000 (yr)
```

```
      Orientation = Random Tumbling
      CS Areal Density = 16.221668 (g/cm^2)
      CS Surface Area = 0.026384 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = No
      Outer Wall 1   Density: 0.427403 (g/cm^2)  Separation: 5.000000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.000000
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

==================================================
Spacecraft = Global-1
Critical Surface = FX+Y
==================================================

**INPUT**

      Apogee Altitude = 550.000000 (km)
      Perigee Altitude = 550.000000 (km)
      Orbital Inclination = 97.590000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004445 (m^2/kg)
      Initial Mass = 54.320000 (kg)
      Final Mass = 54.320000 (kg)
      Station Kept = No
      Start Year = 2018.000000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 38.073997 (g/cm^2)
      CS Surface Area = 0.011241 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = No
      Outer Wall 1   Density: 0.383772 (g/cm^2)  Separation: 5.000000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.000000
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

==================================================
Spacecraft = Global-1
Critical Surface = Battery+X
==================================================

**INPUT**
```

```
      Apogee Altitude = 550.000000 (km)
      Perigee Altitude = 550.000000 (km)
      Orbital Inclination = 97.590000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004445 (m^2/kg)
      Initial Mass = 54.320000 (kg)
      Final Mass = 54.320000 (kg)
      Station Kept = No
      Start Year = 2018.000000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 9.276438 (g/cm^2)
      CS Surface Area = 0.017248 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = No
      Outer Wall 1   Density: 0.427403 (g/cm^2)  Separation: 1.000000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.000001
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

==================================================
Spacecraft = Global-1
Critical Surface = Battery+Y
==================================================

**INPUT**

      Apogee Altitude = 550.000000 (km)
      Perigee Altitude = 550.000000 (km)
      Orbital Inclination = 97.590000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004445 (m^2/kg)
      Initial Mass = 54.320000 (kg)
      Final Mass = 54.320000 (kg)
      Station Kept = No
      Start Year = 2018.000000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 17.006803 (g/cm^2)
      CS Surface Area = 0.009408 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = No
      Outer Wall 1   Density: 0.383772 (g/cm^2)  Separation: 1.000000 (cm)

**OUTPUT**
```

```
      Probabilty of Penitration = 0.000000
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

==================================================
Spacecraft = Global-1
Critical Surface = Tank+Y
==================================================

**INPUT**

      Apogee Altitude = 550.000000 (km)
      Perigee Altitude = 550.000000 (km)
      Orbital Inclination = 97.590000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004445 (m^2/kg)
      Initial Mass = 54.320000 (kg)
      Final Mass = 54.320000 (kg)
      Station Kept = No
      Start Year = 2018.000000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 1.672847 (g/cm^2)
      CS Surface Area = 1.003839 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = Yes
      Outer Wall 1   Density: 0.676247 (g/cm^2)  Separation: 10.000000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.001373
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

==================================================
Spacecraft = Global-1
Critical Surface = Tank+X
==================================================

**INPUT**

      Apogee Altitude = 550.000000 (km)
      Perigee Altitude = 550.000000 (km)
      Orbital Inclination = 97.590000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.004445 (m^2/kg)
      Initial Mass = 54.320000 (kg)
```

```
      Final Mass = 54.320000 (kg)
      Station Kept = No
      Start Year = 2018.000000 (yr)
      Duration = 3.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 1.672847 (g/cm^2)
      CS Surface Area = 0.707557 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = Yes
      Outer Wall 1   Density: 0.427403 (g/cm^2)  Separation: 10.000000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.003181
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range


09 28 2017; 11:38:58AM  Processing Requirement 4.6    Return Status :  Passed

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

**INPUT**

      Space Structure Name = Global-1
      Space Structure Type = Payload

      Perigee Altitude = 550.000000 (km)
      Apogee Altitude = 550.000000 (km)
      Inclination = 97.590000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Area-To-Mass Ratio = 0.004445 (m^2/kg)
      Start Year = 2018.000000 (yr)
      Initial Mass = 58.080000 (kg)
      Final Mass = 54.320000 (kg)
      Duration = 3.000000 (yr)
      Station Kept = False
      Abandoned = True
      PMD Perigee Altitude = 548.898882 (km)
      PMD Apogee Altitude = 548.898882 (km)
      PMD Inclination = 97.641317 (deg)
      PMD RAAN = 359.660653 (deg)
      PMD Argument of Perigee = 1.693062 (deg)
      PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

      Suggested Perigee Altitude = 548.898882 (km)
```

```
      Suggested Apogee Altitude = 548.898882 (km)
      Returned Error Message = Passes LEO reentry orbit criteria.

      Released Year = 2034 (yr)
      Requirement = 61
      Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
09 28 2017; 11:39:02AM  *********Processing Requirement 4.7-1
      Return Status :  Passed

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

name = Global-1
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 54.320000
Thermal Mass = 54.320000
Diameter/Width = 0.500000
Length = 0.845000
Height = 0.450000

name = Payload Deck
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 12.770090
Thermal Mass = 5.400000
Diameter/Width = 0.450000
Length = 0.500000

name = Telescope
quantity = 1
parent = 2
materialID = 5
type = Cylinder
Aero Mass = 5.860000
Thermal Mass = 5.860000
Diameter/Width = 0.300000
Length = 0.478000

name = Camera
quantity = 1
parent = 2
materialID = -2
type = Box
```

```
Aero Mass = 0.319000
Thermal Mass = 0.319000
Diameter/Width = 0.045000
Length = 0.045000
Height = 0.039000

name = Star Tracker
quantity = 2
parent = 2
materialID = 5
type = Cylinder
Aero Mass = 0.158000
Thermal Mass = 0.158000
Diameter/Width = 0.100000
Length = 0.120000

name = IMU
quantity = 2
parent = 2
materialID = 8
type = Box
Aero Mass = 0.055000
Thermal Mass = 0.055000
Diameter/Width = 0.038600
Length = 0.044800
Height = 0.021500

name = Magnetometer 1
quantity = 1
parent = 2
materialID = 8
type = Box
Aero Mass = 0.080090
Thermal Mass = 0.080090
Diameter/Width = 0.043000
Length = 0.099170
Height = 0.017000

name = DC-DC Converter 1
quantity = 5
parent = 2
materialID = 8
type = Box
Aero Mass = 0.137000
Thermal Mass = 0.137000
Diameter/Width = 0.077500
Length = 0.083000
Height = 0.018230

name = Antenna Deck
quantity = 1
parent = 1
```

```
materialID = 8
type = Flat Plate
Aero Mass = 1.173090
Thermal Mass = 0.363000
Diameter/Width = 0.450000
Length = 0.500000

name = X-Band Antenna
quantity = 1
parent = 9
materialID = 8
type = Flat Plate
Aero Mass = 0.300000
Thermal Mass = 0.300000
Diameter/Width = 0.103403
Length = 0.149936

name = S-Band Antenna
quantity = 1
parent = 9
materialID = 8
type = Flat Plate
Aero Mass = 0.120000
Thermal Mass = 0.120000
Diameter/Width = 0.083820
Length = 0.083820

name = Magnetometer 2
quantity = 1
parent = 9
materialID = 8
type = Box
Aero Mass = 0.080090
Thermal Mass = 0.080090
Diameter/Width = 0.045000
Length = 0.099170
Height = 0.017000

name = Coarse Sun Sensor
quantity = 2
parent = 9
materialID = 8
type = Cylinder
Aero Mass = 0.005000
Thermal Mass = 0.005000
Diameter/Width = 0.015300
Length = 0.064000

name = UHF Patch
quantity = 1
parent = 9
materialID = -2
```

```
type = Flat Plate
Aero Mass = 0.300000
Thermal Mass = 0.300000
Diameter/Width = 0.088900
Length = 0.088900

name = Propulsion Deck
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 13.033000
Thermal Mass = 5.400000
Diameter/Width = 0.450000
Length = 0.500000

name = Tank 1
quantity = 1
parent = 15
materialID = 5
type = Cylinder
Aero Mass = 3.440000
Thermal Mass = 3.440000
Diameter/Width = 0.159766
Length = 0.249936

name = Tank 2
quantity = 1
parent = 15
materialID = 5
type = Cylinder
Aero Mass = 3.440000
Thermal Mass = 3.440000
Diameter/Width = 0.159766
Length = 0.249936

name = Valve Assembly
quantity = 1
parent = 15
materialID = 8
type = Box
Aero Mass = 0.210000
Thermal Mass = 0.210000
Diameter/Width = 0.046355
Length = 0.096500
Height = 0.025400

name = HEX
quantity = 1
parent = 15
materialID = 54
type = Box
```

```
Aero Mass = 0.388000
Thermal Mass = 0.388000
Diameter/Width = 0.054940
Length = 0.127000
Height = 0.007620

name = Couse Sun Sensor
quantity = 4
parent = 15
materialID = 8
type = Cylinder
Aero Mass = 0.005000
Thermal Mass = 0.005000
Diameter/Width = 0.015300
Length = 0.064000

name = Fine Sun Sensor
quantity = 1
parent = 15
materialID = 5
type = Box
Aero Mass = 0.035000
Thermal Mass = 0.035000
Diameter/Width = 0.032000
Length = 0.034000
Height = 0.021000

name = UHF Patch Antenna
quantity = 1
parent = 15
materialID = 8
type = Flat Plate
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.088900
Length = 0.088900

name = Avionics Deck
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 18.226700
Thermal Mass = 5.400000
Diameter/Width = 0.450000
Length = 0.500000

name = PCU
quantity = 1
parent = 23
materialID = 5
type = Box
```

```
Aero Mass = 0.990000
Thermal Mass = 0.990000
Diameter/Width = 0.147000
Length = 0.202000
Height = 0.050000

name = Battery
quantity = 2
parent = 23
materialID = -1
type = Box
Aero Mass = 1.600000
Thermal Mass = 1.600000
Diameter/Width = 0.098000
Length = 0.176000
Height = 0.096000

name = DC-DC Converter 2
quantity = 3
parent = 23
materialID = 8
type = Box
Aero Mass = 0.137000
Thermal Mass = 0.137000
Diameter/Width = 0.077500
Length = 0.083000
Height = 0.018230

name = X-Band Radio
quantity = 1
parent = 23
materialID = 8
type = Box
Aero Mass = 1.000000
Thermal Mass = 1.000000
Diameter/Width = 0.115000
Length = 0.160000
Height = 0.046000

name = S-Band Radio
quantity = 1
parent = 23
materialID = 8
type = Box
Aero Mass = 0.200000
Thermal Mass = 0.200000
Diameter/Width = 0.050000
Length = 0.135000
Height = 0.025000

name = UHF Radio/Splitter
quantity = 1
```

```
parent = 23
materialID = 54
type = Box
Aero Mass = 0.230000
Thermal Mass = 0.230000
Diameter/Width = 0.057150
Length = 0.082550
Height = 0.015748

name = FC
quantity = 1
parent = 23
materialID = 8
type = Box
Aero Mass = 4.280000
Thermal Mass = 4.280000
Diameter/Width = 0.121920
Length = 0.216408
Height = 0.092202

name = Reaction Wheels
quantity = 4
parent = 23
materialID = 8
type = Box
Aero Mass = 0.226000
Thermal Mass = 0.226000
Diameter/Width = 0.140000
Length = 0.140000
Height = 0.041900

name = Torque Rods
quantity = 3
parent = 23
materialID = 54
type = Cylinder
Aero Mass = 0.420000
Thermal Mass = 0.420000
Diameter/Width = 0.022220
Length = 0.227000

name = GPS Receiver
quantity = 1
parent = 23
materialID = 54
type = Box
Aero Mass = 0.214700
Thermal Mass = 0.214700
Diameter/Width = 0.057150
Length = 0.060320
Height = 0.012060
```

```
name = DC-DC Converter 3
quantity = 1
parent = 23
materialID = 8
type = Box
Aero Mass = 0.137000
Thermal Mass = 0.137000
Diameter/Width = 0.077500
Length = 0.083000
Height = 0.018230

name = Solar Array
quantity = 1
parent = 1
materialID = 24
type = Flat Plate
Aero Mass = 3.800000
Thermal Mass = 3.800000
Diameter/Width = 0.665000
Length = 0.845000

name = Radiating Side Panel
quantity = 2
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.700000
Thermal Mass = 0.700000
Diameter/Width = 0.380000
Length = 0.431000

name = Support Strut
quantity = 2
parent = 1
materialID = 8
type = Box
Aero Mass = 0.144000
Thermal Mass = 0.144000
Diameter/Width = 0.150000
Length = 0.582000
Height = 0.020000

name = Front Side Panel
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.700000
Thermal Mass = 0.700000
Diameter/Width = 0.380000
Length = 0.480000
```

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

name = Global-1
Demise Altitude = 77.997965
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Payload Deck
Demise Altitude = 68.885222
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Telescope
Demise Altitude = 58.509975
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Camera
Demise Altitude = 68.885222
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Star Tracker
Demise Altitude = 67.341347
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = IMU
Demise Altitude = 66.264402
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Magnetometer 1
Demise Altitude = 66.786863
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = DC-DC Converter 1
Demise Altitude = 65.303589
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Antenna Deck
```

```
Demise Altitude = 77.366926
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = X-Band Antenna
Demise Altitude = 72.430761
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = S-Band Antenna
Demise Altitude = 73.483230
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Magnetometer 2
Demise Altitude = 75.139793
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Coarse Sun Sensor
Demise Altitude = 76.988777
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = UHF Patch
Demise Altitude = 77.366926
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Propulsion Deck
Demise Altitude = 68.921589
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Tank 1
Demise Altitude = 57.402026
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Tank 2
Demise Altitude = 57.402026
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
************************************
name = Valve Assembly
Demise Altitude = 64.311054
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = HEX
Demise Altitude = 0.000000
Debris Casualty Area = 0.439607
Impact Kinetic Energy = 439.511475

************************************
name = Couse Sun Sensor
Demise Altitude = 68.593847
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Fine Sun Sensor
Demise Altitude = 66.532441
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = UHF Patch Antenna
Demise Altitude = 65.786589
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Avionics Deck
Demise Altitude = 69.427870
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = PCU
Demise Altitude = 61.972105
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Battery
Demise Altitude = 69.427870
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = DC-DC Converter 2
Demise Altitude = 66.458191
Debris Casualty Area = 0.000000
```

```
Impact Kinetic Energy = 0.000000

*************************************
name = X-Band Radio
Demise Altitude = 61.091561
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = S-Band Radio
Demise Altitude = 66.526620
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = UHF Radio/Splitter
Demise Altitude = 0.000000
Debris Casualty Area = 0.428833
Impact Kinetic Energy = 185.780930

*************************************
name = FC
Demise Altitude = 50.213670
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Reaction Wheels
Demise Altitude = 67.211089
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Torque Rods
Demise Altitude = 60.848722
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = GPS Receiver
Demise Altitude = 0.000000
Debris Casualty Area = 0.416913
Impact Kinetic Energy = 217.243118

*************************************
name = DC-DC Converter 3
Demise Altitude = 66.458191
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Solar Array
```

```
Demise Altitude = 0.000000
Debris Casualty Area = 1.821465
Impact Kinetic Energy = 419.443970

*************************************
name = Radiating Side Panel
Demise Altitude = 76.037082
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Support Strut
Demise Altitude = 77.549590
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Front Side Panel
Demise Altitude = 76.245402
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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

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

ODAR Section 8: Assessment for Tether Missions

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

END of ODAR for Global-1