HSAT-1

Exhibit 2:

ORBITAL DEBRIS ASSESSMENT REPORT (ODAR)

for

HSAT-1

Stephen T. Gillespie, P.E.

Harris Corporation

Document 7052742, Revision –

11 August 2016

ORBITAL DEBRIS ASSESSMENT REPORT (ODAR)

FOR

HSAT-1

Prepared By: ____________________

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Revision Record

Revision	Authority	Description	Approval Date
-	NR00201579	Initial Release	11 August 2016

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I. Self-assessment and OSMA 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. 1. The launch vehicle is an Indian Space Research Organization (ISRO) Polar Satellite Launch Vehicle (PSLV), slated for launch in Q2 2017. HSAT-1 is not the prime payload, nor is contracted directly to the launch provider for the main mission. HSAT-1 is a secondary payload on this launch vehicle contracted through Spaceflight Inc. as a manifested rideshare. The launch vehicle and launch delivery to orbit is controlled by ISRO, therefore Harris Corporation and HSAT-1 assumes no responsibility for calculation of orbital debris and reentry hazards associated with the launch vehicle.

Orbital Debris Self-Assessment Report Evaluation: HSAT-1 Mission

Requirement	Launch Vehicle				Spacecraft			Comments
	Compliant	Not Compliant	Incomplete	Standard Non-Compliant	Compliant	Not Compliant	Incomplete	
4.3-1(a)	Not Applicable				YES			There are no intentional releases of objects of any size. Compliant as not applicable.
4.3-1(b)					YES			There are no intentional releases of objects of any size. Compliant as not applicable.
4.3-2					YES			There are no intentional releases of objects of any size. Compliant as not applicable.
4.4-1					YES			
4.4-2					YES			
4.4-3					YES			Compliant as not applicable. No planned breakups.
4.4-4					YES			Compliant as not applicable. No planned breakups.
4.5-1					YES			
4.5-2					YES			
4.6-1(a)					YES			Re-entry expected to occur 4.3 years after launch.
4.6-1(b)					YES			Compliant as not applicable. Orbital decay and reentry of HSAT-1 will occur by natural atmospheric forces.
4.6-1(c)					YES			Compliant as not applicable. Orbital decay and reentry of HSAT-1 will occur by natural atmospheric forces.
4.6-2					YES			Compliant as not applicable. HSAT-1 orbit is 500km LEO.
4.6-3					YES			Compliant as not applicable. HSAT-1 orbit is 500km LEO.
4.6-4					YES			Compliant as not applicable. No post-mission disposal operations.
4.7-1					YES			
4.8-1					YES			Compliant as not applicable (no tethers used).

II. Assessment Report Format

ODAR Technical Sections Format Requirements:

This ODAR follows the format in NASA-STD-8719.14, Appendix A.1 and includes the content indicated at a minimum in each section 1 through 8 below for the HSAT-1 satellite. Sections 9 through 14 apply to the launch vehicle ODAR and are not covered here nor are they the responsibility of HSAT-1. DAS software used in this analysis: DAS V2.0.2.

III. References

A. NASA Procedural Requirements for Limiting Orbital Debris Generation, NPR8715.6A, 5 February 2008
B. Process for Limiting Orbital Debris, NASA-STD-8719.14A, 25 May 2012

1.0 Program Management and Mission Overview

Table 1-1: Program Management and Mission Overview

Program/Project Manager:	**Anthony Wade**
Principal Investigator:	Stephen Gillespie
Chief Engineer:	Michael Adams
Chief Technologist/Scientist:	Joshua Bruckmeyer
Foreign government or space agency participation:	Antrix / ISRO (contracted through Spaceflight Inc.)
NASA Involvement:	None
Mission Preliminary Design Review:	July 14, 2016
Mission Critical Design Review:	August 30, 2016
PSRP / MSPSP:	February 15, 2017
Launch:	Q2 2017
Launch Vehicle:	Indian PSLV
Launch Site:	Satish Dhawan Space Centre, Sriharikota, Andhra Pradesh, India
Release from PSLV:	Typically within 3 hours from launch
Mission Duration	24 months from launch
Launch and deployment profile, including all parking, transfer, and operational orbits with apogee, perigee, and inclination:	Sun-Synchronous Orbit (SSO, circular) at 500km, 97.4° inclination, 09:30 Local Time Descending Node (LTDN).
Interaction or potential physical interference with other operational Spacecraft:	Negligible. See this section and Section 5.2

HSAT-1 is an Internal Research and Design (IR&D) testbed funded by Harris Corporation that will test and characterize the performance of a Harris payload in Low Earth Orbit (LEO), as well as demonstrate and characterize the performance of a deployable antenna design. This satellite will be owned and operated wholly by Harris Corporation and has no association with NASA. HSAT-1 is a 6U sized cubesat that will be stowed into a Planetary Systems Corporation (PSC) Containerized Satellite Dispenser (CSD), which will be mounted onto the launch vehicle. The launch vehicle is an Indian Space Research Organization (ISRO) Polar Satellite Launch Vehicle (PSLV), slated for launch in Q2 2017. HSAT-1 is not the prime payload, nor is contracted directly to the launch provider for the main mission. HSAT-1 is a secondary payload on this launch vehicle contracted through Spaceflight Inc. as a manifested rideshare. The launch vehicle and launch delivery to orbit is controlled by ISRO, therefore Harris Corporation and HSAT-1 assumes no responsibility for calculation of orbital debris and reentry hazards associated with the launch vehicle.

The satellite will be launched from the PSLV from the SHAR (Sriharikota) Spaceport (Satish Dhawan Space Center) in Q2 of 2017, and will be inserted into a Sun-Synchronous Orbit (SSO) at 500km, 09:30 Local Time Descending Node (LTDN). This orbit was selected in order to place the payload in an enveloping space radiation environment, as lower inclinations do not adequately cover polar regions. Radio transmission will begin no earlier than 30 minutes after separation from the launch vehicle.

Atmospheric friction will slow the satellite and reduce the altitude of the orbit, until de-orbiting occurs approximately 4.3 years after launch and will conclude the mission.

The PSC CSD utilizes a spring-driven system to assist the deployment of the satellite once the door is opened and the restraint rails are released. The satellite will be released at 1.00-1.40 m/s orthogonal to the initial orbital velocity vector. The HSAT-1 satellite does not contain propellants nor a propulsion system and therefore cannot actively change orbits. HSAT-1 will lose altitude and slow down due to atmospheric friction until disintegration upon atmospheric re-entry.

As shown in Section 5.2 of this document, there is negligible probability that HSAT will interfere with any other spacecraft. HSAT will be ejected from the dispenser orthogonal to the direction of the launch vehicle velocity at approximately 1.0-1.4 m/s. No other ejections will occur from the launch vehicle at the same time HSAT is being deployed from the dispenser.

The satellite will not be powered on until after separation from the launch vehicle. During separation from the launch vehicle and container, the solar panels are passively deployed. Immediately after separation, the satellite bus will power on and boot the GNC system. Approximately 2 minutes after separation, the satellite will orient the panels towards the sun and enter a sun-safe charging mode. This mode will continue until 30 minutes after separation, when RF transmissions are allowed. During this charging mode, no payload operation including antenna deployments will be performed. There is negligible risk that the HSAT-1 satellite will interfere with any other spacecraft during this time, especially since:

- No RF transmissions are allowed, hence no EMI impact to other spacecraft
- HSAT-1 does not contain propulsion, hence it cannot alter its separation trajectory and resulting orbit

2.0 Spacecraft Description

2.1 Physical description of the spacecraft:

HSAT-1 is a 6U microsatellite with stowed dimensions of 10 cm X 20 cm X 30 cm and a total mass not to exceed 13.2 kg. The deployed dimensions are outlined in Figure 2-1. The HSAT spacecraft bus is manufactured by Blue Canyon Technologies, Inc, and occupies 2U of the total 6U bus. The spacecraft bus contains the following subsystems:

- Electrical Power Subsystem (EPS)
    - Includes lithium-ion batteries and power regulation
    - Heaters and temperature telemetry are included with batteries
- Solar Panels (4 panels that measure 20 cm X 30 cm each)
- Attitude Determination and Control Subsystem (ADCS)
    - Sensors (sun sensors and star trackers)
    - 3-axis reaction wheels for fine pointing
    - Torque rods for coarse pointing & desaturation
- Command & Data Handling Subsystem (CD&H)
- Communications Subsystem, Telemetry Tracking & Control (TT&C)
    - Globalstar duplex radio with antenna
    - Tethers Unlimited S-band radio with antenna
- GPS Subsystem
- Chassis Structure and panels (aluminum)
- Interconnects/Cabling

The payload occupies 4U of the total 6U and contains the following components:

- One deployable AIS Monopole Antenna
- One Broad Bandwidth Deployable Antenna (BBDA)
- A deployable mast (graphite composite laminate) used to deploy the BBDA
- Receiver and processing electronics for the antennas

2.2 Illustration of the Spacecraft

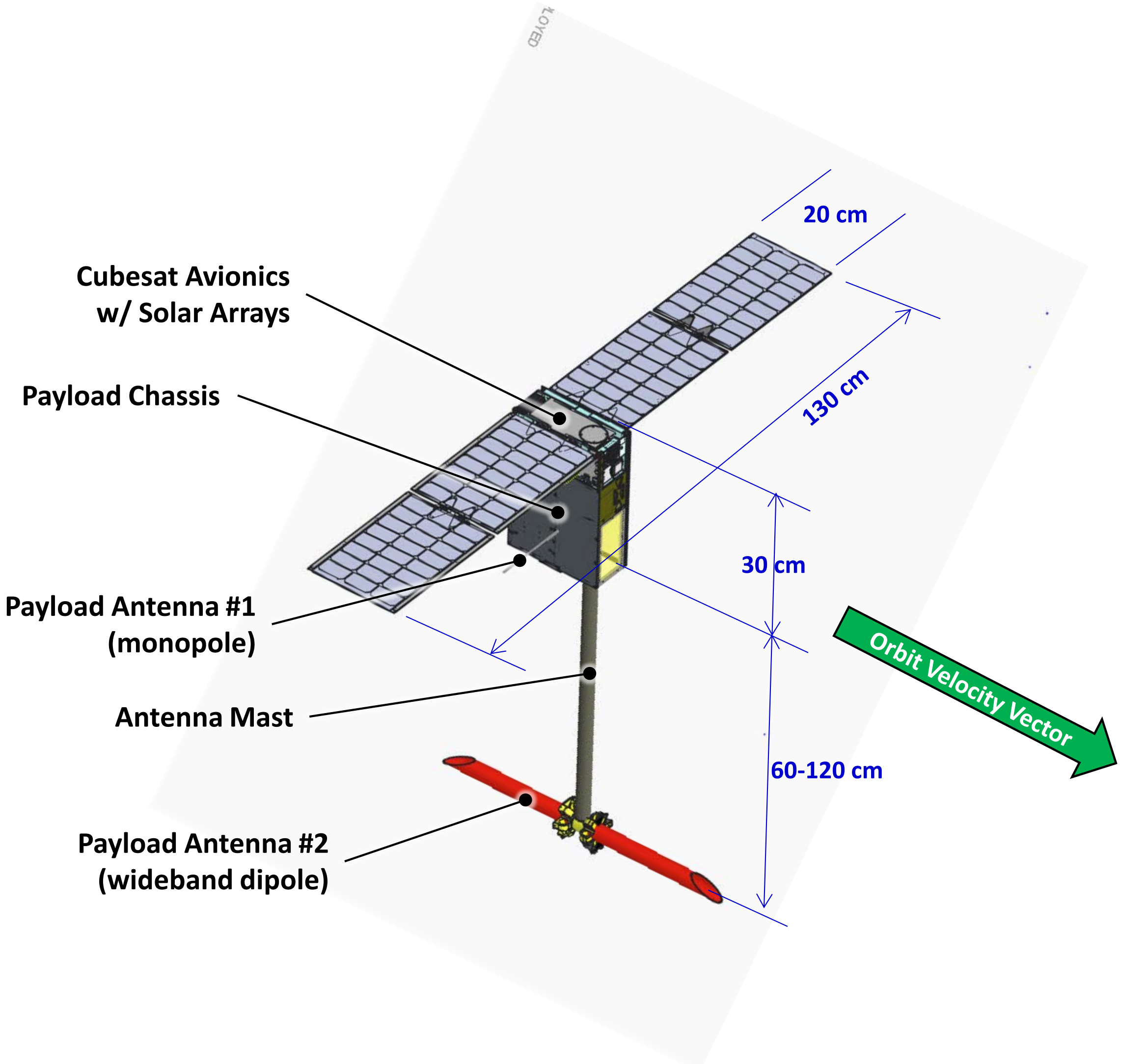

Figure 2-1: Illustration of HSAT-1

2.3 Total satellite mass at launch, including all propellants and fluids:

The total satellite mass at launch is ≤13.2 kg. HSAT-1 does not contain propellants or fluids.

2.4 Dry mass of satellite at launch, excluding solid rocket motor propellants:

The total satellite dry mass is ≤13.2 kg. HSAT-1 does not contain solid rocket motor propellants, or propellants of any kind.

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

Not applicable, no propulsion systems included on HSAT-1

2.6 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:

No fluids or gases are included on HSAT-1

2.7 Description of all fluid systems, including size, type, and qualifications of fluid containers such as propellant and pressurization tanks, including pressurized batteries:

Not applicable. HSAT-1 uses unpressurized standard Lithium-Ion battery cells. No propulsion systems, gases, propellants, nor heat pipes are included on HSAT-1.

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

HSAT-1 has active attitude control capability comprised of 3 reaction wheels and 3 electromagnetic torque rods, each oriented in 3 orthogonal axes.

The nominal orientation of the spacecraft with respect to the orbital velocity vector is shown in Figure 2-1, with the solar panels pointed to the sun.

2.9 Description of any range safety or other pyrotechnic devices:

Not applicable. HSAT-1 does not utilize any pyrotechnic devices or range safety devices.

2.10 Description of the electrical generation and storage system:

The electrical power will be generated using four deployable solar panels constructed of third-generation triple-junction (ZTJ) InGaP/InGaAs/Ge solar cells. Electrical power will be stored using nine cylindrical 2.8 amp-hour Lithium Ion battery cells connected in series and parallel to make a 12 Volt battery pack with 8.4 amp-hour total capacity. The battery cells are manufactured by LG (Part Number LG 18650) and are 65.1mm long and 18.3mm diameter.

The battery cell case includes vent disks. Each cell has a Positive Temp Coefficient (PTC) fuse and a Current Interrupt Device (CID) to protect against an overcurrent condition. The battery cells are UL listed and have not been modified. HSAT will have an integrated charge controller that provides protection for over voltage, under voltage and over temperature. Battery temperature is also managed utilizing a thermostat and heater which are set to keep the batteries above 0°C. Once installed in the launch dispenser, the battery is disconnected and will not be powered until separation from the dispenser. The battery cell bracket and enclosure cover are aluminum and plated with a non-conductive hard anodize coating.

2.11 Identification of any other sources of stored energy not noted above:

The antennas have parts that are unfurlable through the stored strain energy of their stowed configuration (coiled). Attitude control is performed by 3 axis reaction wheels, which spin during operation. Wheel momentum saturation is managed and slowly dissipated through use of the electromagnetic torque rods.

2.12 Identification of any radioactive materials on board:

HSAT-1 does not utilize radioactive materials.

3.0 Assessment of Spacecraft Debris Released during Normal Operations

3.1 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 of any objects of any size.

3.2 Rationale/necessity for release of each object:

Not applicable. HSAT-1 does not intentionally generate debris.

3.3 Time of release of each object, relative to launch time:

Not applicable. HSAT-1 does not intentionally generate debris.

3.4 Release velocity of each object with respect to spacecraft:

Not applicable. HSAT-1 does not intentionally generate debris.

3.5 Expected orbital parameters (apogee, perigee, and inclination) of each object after release:

Not applicable. HSAT-1 does not intentionally generate debris.

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

Not applicable. HSAT-1 does not intentionally generate debris.

3.7 Assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2 (per DAS v2.0)

3.7.1 Requirement 4.3-1, Mission Related Debris Passing Through LEO

Requirement 4.3-1a: All debris released during the deployment, operation, and disposal phases shall be limited to a maximum orbital lifetime of 25 years from date of release (Requirement 56398).

- COMPLIANT (as not applicable). HSAT-1 does not intentionally generate debris.

Requirement 4.3-1b: The total object-time product shall be no larger than 100 object-years per mission (Requirement 56399).

- COMPLIANT (as not applicable). HSAT-1 does not intentionally generate debris.

3.7.2 Requirement 4.3-2, Mission Related Debris Passing Near GEO

Requirement 4.3-2: Debris passing near GEO: For missions leaving debris in orbits with the potential of traversing GEO (GEO altitude +/- 200 km and +/- 15 degrees latitude), released debris with diameters of 5 cm or greater shall be left in orbits which will ensure that within 25 years after release the apogee will no longer exceed GEO - 200 km (Requirement 56400).

- COMPLIANT (as not applicable). HSAT-1 does not pass near GEO, nor intentionally generates debris.

4.0 Assessment of Spacecraft Intentional Breakups and Potential for Explosions

4.1 Identification of all potential causes of spacecraft breakup during deployment and mission operations:

Other than a collision with a micrometeoroid or space debris, there is no credible scenario that would result in spacecraft breakup during normal deployment and operations. The following sections describe battery cell deflagration, which is highly unlikely and is contained by the spacecraft chassis. The 3-axis reaction wheel system is also well contained and poses negligible risk in causing spacecraft breakup.

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

On-orbit failure of a battery cell protection circuit could lead to a short circuit resulting in overheating and a very remote possibility of battery cell deflagration. Multiple independent failures must first occur for this effect. In the event of an unlikely explosion, the effect to the far-term LEO environment is considered negligible due to the following:

- HSAT has a short orbital life due to the low orbital altitude (<5 years)
- HSAT has relatively low mass
- HSAT's spacecraft structural aluminum covers will likely contain debris resulting from a battery rupturing, except for those that may be vented through small orifices.

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

Not applicable. There are no planned breakups.

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

At the end of the mission, Harris will command the satellite to perform the following:

- Orient the solar panels 180° from sun
- Introduce momentum bias to the high inertia axis
- Turn off reaction wheels (wheels will being to de-spin)
- Drain battery and shed power from electronics

Due to the momentum bias, the spacecraft will not rotate back to the sun prior to battery depletion. No other steps are planned for passivation.

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

Not applicable.

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

4.6.1 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:

Requirement 4.4-1: 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 (calculated by DAS 2.0.2):
  - Required Probability: 0.001.
  - Expected probability: 0.000
- Supporting Rationale and FMEA details:
  - No sealed or enclosed cavities are included in the HSAT-1 satellite. All enclosures are properly vented to allow over 6.20 kPa/s pressure change rate.
  - Battery deflagration is a very low risk as discussed in Section 4.2.

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

Requirement 4.4-2: 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 post mission 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).

- HSAT-1 is COMPLIANT via method discussed in Paragraph 4.4

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

Not applicable. There are no planned breakups.

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

Not applicable. There are no planned breakups.

5.0 Assessment of Spacecraft Potential for On-Orbit Collisions

5.1 Assumptions and Analysis

Since the spacecraft will be passivated and de-powered after completion of mission, re-entry will not be controlled and the “random tumbling” scenario was utilized for the DAS analysis. Also, a conservative approach was taken and the “critical surfaces” were considered to be the each total facet size of the 6U cubesat.

5.2 Calculation of spacecraft probability of collision with space objects larger than 10 cm in diameter during the orbital lifetime of the spacecraft

Large Object Impact and Debris Generation Probability: 0.000001%

5.3 Calculation of spacecraft probability of collision with space objects, including orbital debris and meteoroids, of sufficient size to prevent post mission disposal

Small Object Impact and Debris Generation Probability: 0.000402 (Random tumbling)

5.4 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).

- HSAT-1 is COMPLIANT per paragraph 5.2 above

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).

- HSAT-1 is COMPLIANT per paragraph 5.3 above

6.0 Assessment of Spacecraft Postmission Disposal Plans and Procedures

6.1 Description of spacecraft disposal option selected

The satellite will de-orbit naturally by orbital decay and atmospheric re-entry. There is no propulsion system. Attitude control is deactivated after power system passivation upon completion of mission duration.

6.2 Identification of all systems or components required to accomplish any post mission disposal operation, including passivation and maneuvering

None

6.3 Plan for any spacecraft maneuvers required to accomplish post mission disposal

None

6.4 Calculation of area-to-mass ratio after post-mission disposal, if the controlled reentry option is not selected

- Spacecraft Mass: 13.2 kg maximum
- Cross-sectional Area: 0.209 m^2
- Area to mass ratio: 0.209/13 = 0.0158 m^2/kg

6.5 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):

6.5.1 Requirement 4.6-1

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 HSAT-1 satellite reentry is COMPLIANT per Requirement 4.6-1.a above. HSAT-1 will re-enter approximately 4.6 years after launch with orbit history as shown in Figure 6-1 (analysis assumes an approximate random tumbling behavior). Requirements 4.6-

1b and 4.6-1c below are non-applicable requirements because HSAT-1 does not perform a controlled reentry nor direct retrieval.

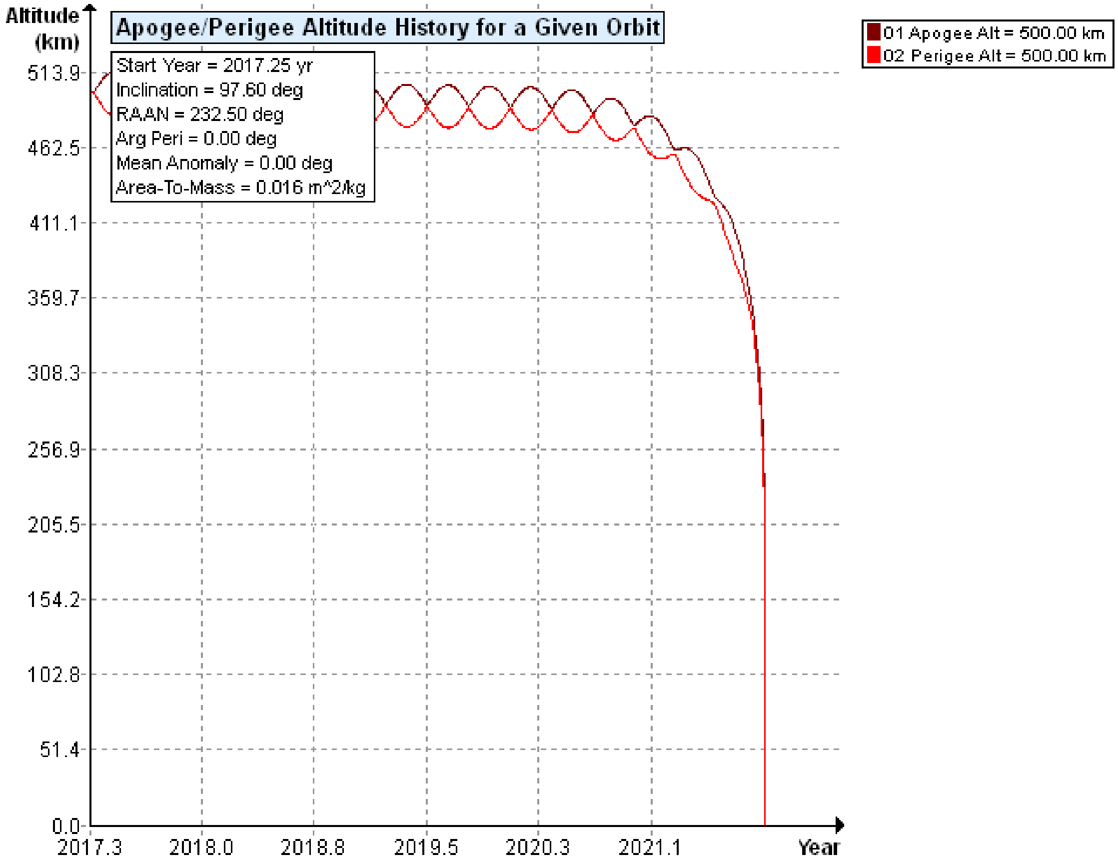

Figure 6-1: HSAT-1 Orbit History

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

Not applicable. HSAT-1 orbit is LEO.

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

Not applicable. HSAT-1 orbit is LEO.

6.5.4 Requirement 4.6-4. Reliability of Post-mission Disposal Operations

Not Applicable. HSAT-1 de-orbiting does not rely on de-orbiting devices.

7.0 Assessment of Spacecraft Reentry Hazards

7.1 Detailed description of spacecraft components

Materials for each object are selected from the standard DAS materials database and no new materials were added. The following properties were applied to HSAT-1 components:

- o Electronic boards / CCAs (Circuit Card Assembly) – Fiberglass
- o Antennas - Stainless steel (generic)
- o Chassis structures and panels – Aluminum 6061-T6
- o Fasteners - A-286
- o Solar arrays – Fiberglass
- o Internal casings and panels - Aluminum 6061-T6
- o Solar array hinges – Titanium (6Al-4V)

7.2 Summary of objects expected to survive an uncontrolled reentry

Only objects of high melting point temperature materials are expected to survive an uncontrolled re-entry. The solar array panel hinges are made of Titanium 6Al-4V, and will survive re-entry with less than 1 Joule of impact energy.

7.3 Calculation of probability of human casualty

Summary Analysis Results: DAS v2.0.2 reports that HSAT-1 is compliant with the requirement. The analysis resulted in the following:

- Analysis is compliant with requirement, risk of casualty is “1:0”
- Solar array panels demise at 77.3 km
- Structure / chassis demise at 58.6 km
- Other components (CCAs & hardware) demise above 58.6 km
- Only the titanium solar panel hinges survive re-entry, with an impact energy of less than 1 Joule (Compliant, < 15J)

7.4 Assessment of spacecraft compliance with Requirement 4.7-1

7.4.1 Requirement 4.7-1. Limit the risk of human casualty

Requirement 4.7-1: 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).
b) 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).
c) 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).

HSAT-1 is COMPLIANT with Requirement 4.7-1 above. Only the titanium solar panel hinges survive re-entry, with an impact energy of less than 1 Joule (Compliant, < 15J).

7.5 Assessment of Spacecraft Hazardous Materials

Not applicable. No hazardous materials are used in HSAT-1

8.0 Assessment for Tether Missions

Not applicable. There are no tethers in the HSAT-1 mission.

9.0 Launch Vehicle Description and Assessment

Not applicable for the following sections outlined NASA-STD 8719.14 Revision A:

9. Launch Vehicle Description
10. Assessment of Launch Vehicle Debris Released During Normal Operations
11. Assessment of Launch Vehicle Potential for Explosions and Intentional Breakups
12. Assessment of Launch Vehicle Potential for On-orbit Collisions
13. Assessment of Launch Vehicle Post-mission Disposal Plans and Procedures
14. Assessment of Launch Vehicle Reentry Hazards
    a. Assessment of Launch Vehicle Hazardous Materials

HSAT-1 is a secondary payload to the Indian ISRO PSLV and assumes the prime payload provider or launch provider is responsible for analysis of launch vehicle debris probability.

APPENDIX A: DAS 2.0.2 LOG FILE

```
08 08 2016; 14:23:57PM  DAS Application Started
08 08 2016; 14:23:58PM  Opened Project C:\Program Files (x86)\NASA\DAS 2.0\project\
08 08 2016; 14:24:02PM  Processing Requirement 4.3-1: Return Status : Not Run

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

=============== End of Requirement 4.3-1 ===============
08 08 2016; 14:24:04PM  Processing Requirement 4.3-2: Return Status : Passed

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

=============== End of Requirement 4.3-2 ===============
08 08 2016; 14:24:07PM  Requirement 4.4-3:  Compliant

=============== End of Requirement 4.4-3 ===============
08 08 2016; 14:24:13PM  Processing Requirement 4.5-1: Return Status : Passed

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

**INPUT**

      Space Structure Name = HSAT
      Space Structure Type = Payload
      Perigee Altitude = 500.000000 (km)
      Apogee Altitude = 500.000000 (km)
      Inclination = 97.400000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass Ratio = 0.015800 (m^2/kg)
      Start Year = 2017.250000 (yr)
      Initial Mass = 13.200000 (kg)
      Final Mass = 13.200000 (kg)
      Duration = 2.000000 (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 = 0.000001
```

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

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

=============== End of Requirement 4.5-1 ===============
08 08 2016; 14:25:49PM  Requirement 4.5-2:  Compliant

==================================================
Spacecraft = HSAT
Critical Surface = X
==================================================

**INPUT**

      Apogee Altitude = 500.000000 (km)
      Perigee Altitude = 500.000000 (km)
      Orbital Inclination = 97.400000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.015800 (m^2/kg)
      Initial Mass = 13.200000 (kg)
      Final Mass = 13.200000 (kg)
      Station Kept = No
      Start Year = 2017.250000 (yr)
      Duration = 2.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 8.612000 (g/cm^2)
      CS Surface Area = 0.153000 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = No

**OUTPUT**

      Probabilty of Penitration = 0.000006
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

==================================================
Spacecraft = HSAT
Critical Surface = Y
==================================================

**INPUT**

      Apogee Altitude = 500.000000 (km)
      Perigee Altitude = 500.000000 (km)
      Orbital Inclination = 97.400000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.015800 (m^2/kg)
      Initial Mass = 13.200000 (kg)
      Final Mass = 13.200000 (kg)
      Station Kept = No
      Start Year = 2017.250000 (yr)
```

```
      Duration = 2.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 11.294000 (g/cm^2)
      CS Surface Area = 0.117000 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = No

**OUTPUT**

      Probabilty of Penitration = 0.000002
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range

==================================================
Spacecraft = HSAT
Critical Surface = Z
==================================================

**INPUT**

      Apogee Altitude = 500.000000 (km)
      Perigee Altitude = 500.000000 (km)
      Orbital Inclination = 97.400000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.015800 (m^2/kg)
      Initial Mass = 13.200000 (kg)
      Final Mass = 13.200000 (kg)
      Station Kept = No
      Start Year = 2017.250000 (yr)
      Duration = 2.000000 (yr)
      Orientation = Random Tumbling
      CS Areal Density = 3.703000 (g/cm^2)
      CS Surface Area = 0.357000 (m^2)
      Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = No

**OUTPUT**

      Probabilty of Penitration = 0.000394
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range


08 08 2016; 14:27:28PM  Processing Requirement 4.6    Return Status :
Passed

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

**INPUT**

      Space Structure Name = HSAT
      Space Structure Type = Payload

      Perigee Altitude = 500.000000 (km)
```

```
      Apogee Altitude = 500.000000 (km)
      Inclination = 97.400000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Area-To-Mass Ratio = 0.015800 (m^2/kg)
      Start Year = 2017.250000 (yr)
      Initial Mass = 13.200000 (kg)
      Final Mass = 13.200000 (kg)
      Duration = 2.000000 (yr)
      Station Kept = False
      Abandoned = True
      PMD Perigee Altitude = 486.622758 (km)
      PMD Apogee Altitude = 495.813659 (km)
      PMD Inclination = 97.366149 (deg)
      PMD RAAN = 357.400132 (deg)
      PMD Argument of Perigee = 153.952521 (deg)
      PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

      Suggested Perigee Altitude = 486.622758 (km)
      Suggested Apogee Altitude = 495.813659 (km)
      Returned Error Message = Passes LEO reentry orbit criteria.

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

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

=============== End of Requirement 4.6 ===============
08 08 2016; 14:27:36PM  *********Processing Requirement 4.7-1
      Return Status :  Passed

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

name = HSAT
quantity = 1
parent = 0
materialID = 8
type = Box
Aero Mass = 13.200000
Thermal Mass = 13.200000
Diameter/Width = 0.200000
Length = 0.300000
Height = 0.100000

name = Solar Array Hinges
quantity = 8
parent = 1
materialID = 65
type = Flat Plate
Aero Mass = 0.012000
Thermal Mass = 0.012000
Diameter/Width = 0.040000
Length = 0.060000
```

```
name = Chassis Structure & Panels
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 10.174000
Thermal Mass = 10.174000
Diameter/Width = 0.200000
Length = 0.300000
Height = 0.100000

name = Solar Array Panels
quantity = 4
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.270000
Thermal Mass = 0.270000
Diameter/Width = 0.200000
Length = 0.300000

name = CCAs
quantity = 4
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.300000
Thermal Mass = 0.300000
Diameter/Width = 0.100000
Length = 0.200000

name = Hardware
quantity = 60
parent = 1
materialID = 57
type = Cylinder
Aero Mass = 0.001000
Thermal Mass = 0.001000
Diameter/Width = 0.005000
Length = 0.012000

name = Antenna
quantity = 13
parent = 1
materialID = 54
type = Flat Plate
Aero Mass = 0.015000
Thermal Mass = 0.015000
Diameter/Width = 0.013000
Length = 0.660000

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

name = HSAT
Demise Altitude = 77.999551
Debris Casualty Area = 0.000000
```

```
Impact Kinetic Energy = 0.000000

*************************************
name = Solar Array Hinges
Demise Altitude = 0.000000
Debris Casualty Area = 3.369502
Impact Kinetic Energy = 0.979098

*************************************
name = Chassis Structure & Panels
Demise Altitude = 58.608796
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Solar Array Panels
Demise Altitude = 77.333605
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = CCAs
Demise Altitude = 76.395551
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Hardware
Demise Altitude = 77.349941
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Antenna
Demise Altitude = 0.000000
Debris Casualty Area = 6.236542
Impact Kinetic Energy = 0.427765

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

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