TechEdSat Formal Orbital Debris Assessment Report (ODAR)

In accordance with NPR 8715.6A, this report is presented as compliance with the required reporting format per NASA-STD-8719.14, APPENDIX A.

Report Version: A (4/2/2012)

DAS Software Used in This Analysis: DAS v2.0

This document is a part of the TechEdSat Satellite Project Documentation, which is controlled by the TechEdSat Project Configuration Manager under the direction of the TechEdSat Satellite Project at NASA, Ames Research Center, Moffett Field, California.

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Record of Revisions				
Rev	**Date**	**Affected Pages**	**Description of Change**	**Author (s)**
A	4/2/2012	All	Initial Release	Ali Guarneros Luna, Christopher Hartney,

Table of Contents

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. In the final ODAR document, this assessment will reflect any inputs received from OSMA as well.

Orbital Debris Self-Assessment Report Evaluation: TechEdSat Mission

Requirement #	Launch Vehicle				Spacecraft			Comments
	Compliant	Not Compliant	Incomplete	Standard Non Compliant	Compliant	Not Compliant	Incomplete	
4.3-1.a			x		x			No Debris Released in LEO. See note 1.
4.3-1.b			x		x			No Debris Released in LEO. See note 1.
4.3-2			x		x			No Debris Released in GEO. See note 1.
4.4-1			x		x			See note 1.
4.4-2			x		x			See note 1.
4.4-3			x		x			No planned breakups. See note 1.
4.4-4			x		x			No planned breakups. See note 1.
4.5-1			x		x			See note 1.
4.5-2					x			
4.6-1(a)			x		x			See note 1.
4.6-1(b)			x		x			See note 1.
4.6-1(c)			x		x			See note 1.
4.6-2			x		x			See note 1.
4.6-3			x		x			See note 1.
4.6-4			x		x			See note 1.
4.6-5			x		x			See note 1.
4.7-1			x		x			See note 1.
4.8-1					x			No tethers used.

Notes:

1. The primary payload belongs to Japan Aerospace Exploration Agency (JAXA). This is a NASA primary mission. All of the other portions of the launch stack are non-NASA and TechEdSat is not the lead.

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 2 through 8 below for the TechEdSat satellite. Sections 9 through 14 apply to the launch vehicle ODAR and are not covered here.

Mission Description:

The Technical Education Satellite will be soft-stowed onto the Japanese HTV-3 launch vehicle where it will be put aboard the International Space Station (ISS). TechEdSat will test and validate two different technologies in Low Earth Orbit (LEO), the first demonstrating the AAC's Plug-and-Play power architecture, and the second using two communication modules: Quake Global's Iridium 9602 and Q1000, which utilizes ORBCOMM.

The satellite will be launched from the International Space Station (ISS) on August 26th, 2012. It will be inserted into an orbit at 413.2 km apogee and 381.3 km perigee, on an inclination from the equator of 51.6° degrees. Transmission will begin 40 minutes after launch from ISS. Atmospheric friction will slow the satellite and reduce the altitude of the orbit, until de-orbiting occurs approximately 105 days after launch and will conclude the mission.

The TechEdSat will fly on the HTV-3 mission, stowed inside the J-SSOD Satellite Install Case. The Satellite Install Case is stowed in a Common Transfer Bag (CTB) during launch. The TechEdSat will be the first one of its kind to be soft-stowed in the ISS and later integrate in the JEM Remote Manipulator System (JEMRMS). This will have a deployer known as the JEM Small Satellite Orbital Deployer (J-SSOD) which will use a spring to "push" the TechEdSat, along with two other CubeSats, at a velocity of 5 cm/sec and at an angle of 45 degrees relative to the ISS. There are no propellants.

Launch vehicle and launch site: Japanese HTV-3, Tsukuba, Japan

Proposed launch date: July 26, 2012

Mission duration: Until de-orbit

Launch and deployment profile, including all parking, transfer, and operational orbits with apogee, perigee, and inclination:
TechEdSat will be launched on a Japanese HTV-3 launch vehicle where it will be transported onto the ISS. It will then be deployed from the JEMRMS by the Japan Aerospace Exploration Agency (JAXA) using the JEM Small Satellite Orbital Deployer (J-SSOD) for the first technical demonstration mission. The interface requirements between the J-SSOD and a satellite are developed based on the CubeSat Design Specification rev.12 published on August 1st, 2009 by the California Polytechnic State University with JEM unique requirements.

This system will allow TechEdSat to be launched at a velocity of 5 cm/sec and at an angle of 45 degrees relative to the JEMRMS into a circular orbit initially approximately 300 or 400 km relative to Earth's surface.

The TechEdSat orbit is defined as follows:

Apogee: 413.2 km

Perigee: 381.3 km

Inclination: 51.6 degrees.

TechEdSat has no propulsion and therefore does not actively change orbits. TechEdSat will lose altitude, then slow down due to atmospheric friction and disintegrate on atmospheric re-entry approximately 105 days after ISS deployment.

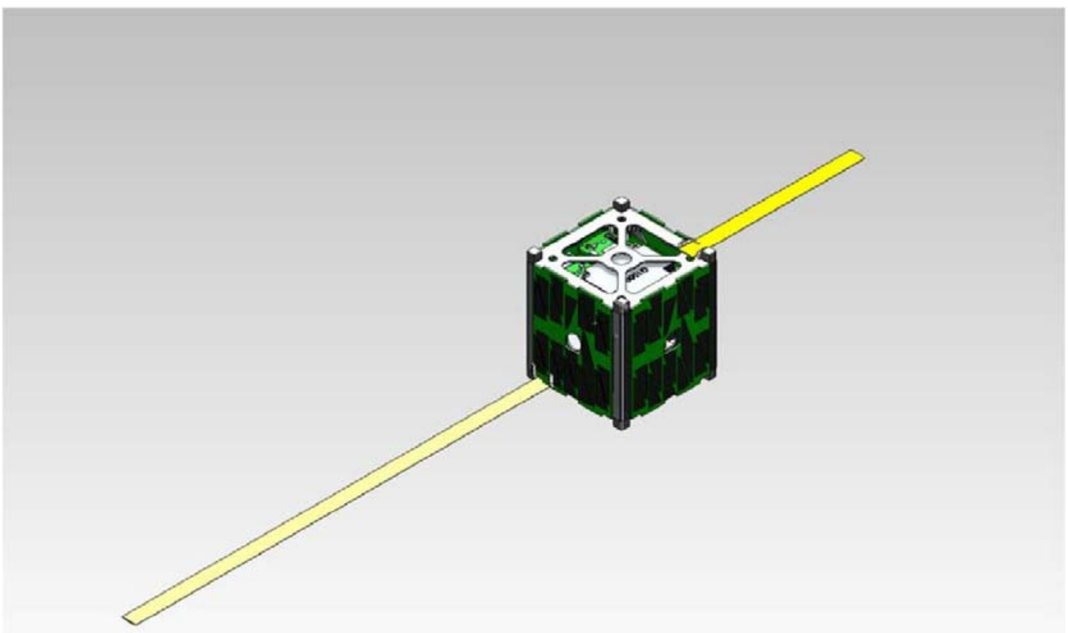

Figure 1: TechEdSat Full View with Antennas Deployed

Interaction or potential physical interference with other operational Spacecraft:

The main risks of this satellite are the Lithium-ion batteries used by the spacecraft (flown in and certified by the ISS program), the radio-frequency noise generated when system power is applied (flown without incident by AAC Microtec in other missions), and the possibility of the TechEdSat impacting the International Space Station after deployment. Since there are two other CubeSats being launched from the same system, and JAXA has shown that the likelihood of any CubeSat impacting the ISS is very minimal, we believe that this will be minimal.

ODAR Section 1: Program Management and Mission Overview

Mission Directorate: ARC CCT Office

Program Executive: John Hines

Program/project Manager: Andres Martinez

Senior Scientist: Marcus Murbach

Senior Management: John Hines and Periklis Papadopoulos

Foreign government or space agency participation: Sweden National Space Board

Summary of NASA's responsibility under the governing agreement(s): Look into the SAA between NASA and SNSB

Schedule of mission design and development milestones from NASA mission selection through proposed launch date, including spacecraft PDR and CDR (or equivalent) dates*:

Mission Selection: SAA	Government agreement sign date
Mission Preliminary Design Review:	December 2nd, 2011
Mission Critical Design Review:	January 25th, 2012
PSRP 0/I:	January 16th, 2012
PSRP I/II:	March 23rd, 2012
Launch:	June 26th, 2012
Release from ISS, Begin Operation	September 7, 2012

ODAR Section 2: Spacecraft Description

Physical description of the spacecraft:
TechEdSat is a 1U nanosatellite with dimensions of 10 cm X 10 cm X 10 cm and a total mass of about 0.95 kg. The TechEdSat payload carries new plug-and-play structures develop by AAC Microtec based out of Sweden. In addition, TechEdSat will have two modules for communication and tracking as a technology demonstration.

TechEdSat will contain the following systems: four miniaturized Remote Terminal Unit devices (nanoRTU), one RTU "lite" device, one MPDU "lite" with a Watchdog timer, one ORBCOMM Q1000-CPM modem, one Iridium 9602 modem, one StenSat beacon, one Canon 930-BP battery, two deployed antennas, one patch antenna, and four temperature sensors.

- The RTU “lite” is the main computer board that will send commands to the subsystems via nanoRTU.
- The nanoRTU will interface with the payloads on the TechEdSat.
- The StenSat beacon will be transmitting location coordinates to the Ground Station, and will include a 12-cm deployed antenna. The Ham Radio community will be invited to participate to collect the beacon call sign.
- The ORBCOMM Q1000-CPM modem will have a 42 cm deployed antenna.
- The Iridium 9602 modem will have a patch antenna.
- There are four temperature sensors that will monitor the temperature of the battery, solar panels and boards inside the CubeSat.

Total satellite mass at launch, including all propellants and fluids: 0.95 kg

Dry mass of satellite at launch, excluding solid rocket motor propellants: 0.95 kg

Description of all propulsion systems (cold gas, mono-propellant, bi-propellant, electric, nuclear): There will be no propulsion systems on TechEdSat.

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.

Not applicable as there will be no fluids or gasses on board.

Fluids in Pressurized Batteries: None. TechEdSat uses unpressurized standard COTS Lithium-Ion battery cells.

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

TechEdSat uses passive magnetic attitude control. The magnets are aligned along the length of the spacecraft so the spacecraft aligns with the Earth’s magnetic field. This means that the satellite cross section presented to the direction of flight varies with location within the Earth’s magnetic field as well as varying due to nutation (coning rotation). The variable tilt toward earth caused by local magnetic inclination should have little effect on orbit decay. Variable magnetic declination effects (angles away from true north) should average out with minimal or no effect.

Description of any range safety or other pyrotechnic devices: The TechEdSat utilizes a NiChrome Wire heating element for use in antenna deployment. The NiChrome is wound in a coil shape with a braided nylon cord strung through its center. The NiChrome wire itself is then crimped into barrel pins at the two ends and soldered to a PCB board interface. The NiChrome cutter is in series with a power resister and has its own software controlled power source dedicated to the action of antenna deployment. The coil is placed inside of a ceramic tube to protect the local structure and elements as well as improve efficient delivery of heat to the nylon wire. This method and design was used successfully on NanoSail D2.

Description of the electrical generation and storage system: The power will be generated using solar panels and Lithium Ion Batteries. The battery that will be used is a Canon BP-930. See attached data sheet (Appendix B). This battery is approved by the ISS for flight. The dimensions of the battery are 4 x 7 x 3.8 cm and the weight is 0.18 kg.

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)

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 nine independent, mutually exclusive failure modes that could lead to a battery explosion.

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:

None.

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

The TechEdSat will only be on orbit for 100 days based on the DAS analysis shown in this report, and it is planned to operate until deorbiting. Therefore, no postmission passivation will be performed, as the satellite will break up on re-entry at the end of the mission.

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:

Payload Pressure Vessel Failure:

The maximum payload pressure is 14.7 PSIa. At this pressure, the payload is considered to be a “sealed container” and not a pressure vessel. This contained pressure is considered to be insufficient to cause catastrophic failure of the vessel.

Battery explosion:

Effect: All failure modes below might 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 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.
Probability: Very Low. It is believed to be less than 0.1% given that multiple independent (not common mode) faults must occur for each failure mode to cause the ultimate effect (explosion).

Failure mode 1: Battery Internal short circuit.

Mitigation 1: Complete proto-qualification and environmental acceptance tests of the Canon BP-930 battery by JSC ISS program. The acceptance tests are 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: Each cell includes a positive temperature coefficient (PTC) variable resistance device that ensures high rate discharge is limited to acceptable levels if thermal rise occurs in the battery.
Combined faults required for realized failure: The PTC must fail **AND** spacecraft thermal design must be incorrect **AND** external over current detection and protection must fail for this failure mode to occur. See Appendix C for more information.

Failure Mode 3: Overcharging and excessive charge rate.

Mitigation 3: The satellite bus battery charging circuit design eliminates the possibility of the batteries being overcharged if circuits function nominally. This circuit has been proto-qualification tested for survival in shock, vibration, and thermal-vacuum environments. The charge circuit disconnects the incoming current when battery voltage indicates normal full charge at 8.4 V. If this circuit fails to operate, continuing charge can cause gas generation. The batteries include overpressure release vents that allow gas to escape, virtually eliminating any explosion hazard.
Combined faults required for realized failure:

1) **For overcharging:** The charge control circuit must fail to function **AND** the PTC device must fail (or temperatures generated must be insufficient to cause the PTC device to modulate) **AND** the overpressure relief device must be inadequate to vent generated gasses at acceptable rates to avoid explosion.
2) **For excessive charge rate:** The maximum charging rate from a single solar panel when in AM 1.5G conditions (in space, perpendicular to the sun) is 124 mA. The maximum charge rate our battery can accept is 3 A. The battery is a proto-qualified

Canon BP-930 from the JSC ISS program, and has four US18650S cells. The battery itself has two parallel strings of 2 cells connected in series, and thus having 4 cells. Due to solar panel current limits and their direction-facing arrangement on the satellite, there is no physical means of exceeding charging rate limits, even if only a single string from the battery was accepting charge. For this failure mode to become active one string must fail to accept a charge **AND** the charge control circuit on the remaining string fails. The overpressure relief vent keeps the battery cells from rupturing, and is thus limited to worst-case effects of overcharging.

Failure Mode 4: 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 4: This failure mode is negated by a) proto-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: The PTC must fail **AND** an external load must fail/short-circuit **AND** external over-current detection and disconnect function must fail to enable this failure mode.

Failure Mode 5: Inoperable vents.

Mitigation 5: Battery vents are not inhibited by the battery holder design or the spacecraft.
Combined effects required for realized failure: The manufacturer fails to install proper venting and ISS environmental stress screening fails to detect failed vents.

Failure Mode 6: Crushing.

Mitigation 6: 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 7: Low level current leakage or short-circuit through battery pack case or due to moisture-based degradation of insulators.

Mitigation 7: 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 failures in environmental tests must occur to result in this failure mode.

Failure Mode 8: Excess temperatures due to orbital environment and high discharge combined.

Mitigation 8: 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** the PTC device must fail **AND** over-current monitoring and control must all fail for this failure mode to occur.

Failure Mode 9: Polarity reversal due to over-discharge caused by continuous load during periods of negative power generation vs. consumption.

Mitigation 9: In nominal operations, the spacecraft EPS design negates this mode because the processor will stop when voltage drops too low, below 7 V. This disables ALL connected loads, creating a guaranteed power-positive charging scenario. The spacecraft will not restart or connect any loads until battery voltage is above the acceptable threshold. At this point, only the safemode processor and Stensat beacon are enabled and charging the battery. Once the battery reaches 90% of the peak voltage (around 7.5 V), it will switch to nominal mode and will be able to receive ground commands for continuing mission functions.
Combined faults required for realized failure: The microcontroller must stop executing code **AND** significant loads must be commanded/stuck "on" **AND** power margin analysis must be wrong **AND** the charge control circuit must 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 post mission disposal or control to a level which can not cause an explosion or deflagration large enough to release orbital debris or break up the spacecraft (Requirement 56450).

Compliance statement:
The TechEdSat will only be on orbit for 100 days based on the DAS analysis shown in this report, and it is planned to operate until deorbiting. Therefore, no postmission passivation will be performed, as the satellite will break up on re-entry at the end of the mission. Therefore, the TechEdSat battery will meet the above requirement.

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, 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: 0.000000; 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: 0.000000; COMPLIANT

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

6.1 Description of spacecraft disposal option selected: The satellite will de-orbit naturally by atmospheric re-entry. There is no propulsion system.

6.2 Plan for any spacecraft maneuvers required to accomplish postmission disposal: None.

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

Spacecraft Mass: 0.95 kg

Cross-sectional Area: 0.015 m^2 (Calculated by DAS 2.0 for the configuration in Figure 1).

Area to mass ratio: 0.015/0.95 = 0.01579 m^2/kg

6.4 Assessment of spacecraft compliance with Requirements 4.6-1 through 4.6-5 (per DAS v 2.0 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.

Analysis: The TechEdSat satellite reentry is COMPLIANT using Method “a.” TechEdSat will re-enter approximately 105 days after launch with orbit history as shown in Figure 2 (analysis assumes an approximate random tumbling behavior).

Figure 2: TechEdSat Orbit History

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

Analysis: Not applicable. TechEdSat orbit is LEO.

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

Analysis: Not applicable. TechEdSat orbit is LEO.

Requirement 4.6-4. Reliability of Postmission Disposal Operations

Analysis: TechEdSat de-orbiting does not rely on de-orbiting devices. Release from the ISS with a downward, retrograde vector will result in de-orbiting in approximately 105 days with no disposal or de-orbiting actions required.

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 reports that TechEdSat is compliant with the requirement. It predicts that no components reach the ground. Also, the Risk of Human Casualty was calculated and reported to be 1:0. This is an erroneous value since no piece of the TechEdSat will reach the ground to cause any human risk. As seen in the analysis outputs below, the impact kinetic energies are 0.000000 Joules and impact casualty areas are all 0.000000 square meters. Also, there are no titanium components that will be used on TechEdSat, which also is a reason why no components reach the ground.

```
03 20 2012; 19:28:32PM  Processing Requirement 4.3-1: Return Status :  Not
Run

=====================
No Project Data Available
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=============== End of Requirement 4.3-1 ===============
03 20 2012; 19:28:39PM  Processing Requirement 4.3-2: Return Status : Passed

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No Project Data Available
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=============== End of Requirement 4.3-2 ===============
03 20 2012; 19:28:42PM  Requirement 4.4-3:  Compliant

=============== End of Requirement 4.4-3 ===============
03 20 2012; 19:28:48PM  Processing Requirement 4.5-1: Return Status :  Passed

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

**INPUT**

      Space Structure Name = TechEdSat
      Space Structure Type = Payload
      Perigee Altitude = 381.300000 (km)
      Apogee Altitude = 413.200000 (km)
      Inclination = 51.600000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass Ratio = 0.015790 (m^2/kg)
      Start Year = 2012.000000 (yr)
      Initial Mass = 0.950000 (kg)
      Final Mass = 0.950000 (kg)
      Duration = 0.290000 (yr)
      Station-Kept = False
      Abandoned = True
      PMD Perigee Altitude = -1.000000 (km)
      PMD Apogee Altitude = -1.000000 (km)
```

```
      PMD Inclination = 0.000000 (deg)
      PMD RAAN = 0.000000 (deg)
      PMD Argument of Perigee = 0.000000 (deg)
      PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

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

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

=============== End of Requirement 4.5-1 ===============
03 20 2012; 19:28:54PM  Requirement 4.5-2:  Compliant
03 20 2012; 19:29:02PM  Processing Requirement 4.6    Return Status :  Passed

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

**INPUT**

      Space Structure Name = TechEdSat
      Space Structure Type = Payload

      Perigee Altitude = 381.300000 (km)
      Apogee Altitude = 413.200000 (km)
      Inclination = 51.600000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Area-To-Mass Ratio = 0.015790 (m^2/kg)
      Start Year = 2012.000000 (yr)
      Initial Mass = 0.950000 (kg)
      Final Mass = 0.950000 (kg)
      Duration = 0.290000 (yr)
      Station Kept = False
      Abandoned = True
      PMD Perigee Altitude = -1.000000 (km)
      PMD Apogee Altitude = -1.000000 (km)
      PMD Inclination = 0.000000 (deg)
      PMD RAAN = 0.000000 (deg)
      PMD Argument of Perigee = 0.000000 (deg)
      PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

      Suggested Perigee Altitude = 381.300000 (km)
      Suggested Apogee Altitude = 413.200000 (km)
      Returned Error Message = Reentry during mission (no PMD req.).
```

```
      Released Year = 2012 (yr)
      Requirement = 61
      Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
03 20 2012; 19:31:16PM  *********Processing Requirement 4.7-1
      Return Status :  Passed

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

name = TechEdSat
quantity = 1
parent = 0
materialID = 8
type = Box
Aero Mass = 0.950000
Thermal Mass = 0.950000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.100000

name = Battery
quantity = 1
parent = 1
materialID = 39
type = Box
Aero Mass = 0.181000
Thermal Mass = 0.181000
Diameter/Width = 0.040000
Length = 0.070000
Height = 0.038000

name = Quake Iridium Modem
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.114000
Thermal Mass = 0.114000
Diameter/Width = 0.064000
Length = 0.064000
Height = 0.016000

name = Iridium Patch Antenna
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.043000
Thermal Mass = 0.043000
```

```
Diameter/Width = 0.043400
Length = 0.046000
Height = 0.011400

name = Iridium 9602
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.027000
Thermal Mass = 0.027000
Diameter/Width = 0.041000
Length = 0.045000
Height = 0.013000

name = Full Size PCP
quantity = 3
parent = 1
materialID = 77
type = Box
Aero Mass = 0.010000
Thermal Mass = 0.010000
Diameter/Width = 0.095000
Length = 0.095000
Height = 0.002000

name = Battery Plate
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.040000
Thermal Mass = 0.040000
Diameter/Width = 0.095000
Length = 0.095000

name = Nano
quantity = 4
parent = 1
materialID = 77
type = Flat Plate
Aero Mass = 0.003000
Thermal Mass = 0.003000
Diameter/Width = 0.032000
Length = 0.032000

name = Nanolite
quantity = 1
parent = 1
materialID = 77
type = Flat Plate
Aero Mass = 0.006000
Thermal Mass = 0.006000
```

```
Diameter/Width = 0.032000
Length = 0.064000

name = Stensat
quantity = 1
parent = 1
materialID = 77
type = Flat Plate
Aero Mass = 0.020000
Thermal Mass = 0.020000
Diameter/Width = 0.045000
Length = 0.080000

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

name = TechEdSat
Demise Altitude = 77.997613
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Battery
Demise Altitude = 77.582230
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Quake Iridium Modem
Demise Altitude = 72.268175
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Iridium Patch Antenna
Demise Altitude = 74.116121
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Iridium 9602
Demise Altitude = 75.467902
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Full Size PCP
Demise Altitude = 77.929722
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Battery Plate
```

```
Demise Altitude = 76.553277
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Nano
Demise Altitude = 77.861277
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Nanolite
Demise Altitude = 77.861277
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Stensat
Demise Altitude = 77.706785
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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

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

Requirements 4.7-1b and 4.7-1c below are non-applicable requirements because TechEdSat 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 in the TechEdSat mission.

END of ODAR for TechEdSat.

Appendix A: Acronyms

AFRL	Air Force Research Lab
ARC	Ames Research Center
Arg peri	Argument of Perigee
CDR	Critical Design Review
cm	centimeter
COTS	Commercial Off-The-Shelf (items)
DAS	Debris Assessment Software
EOM	End Of Mission
ESMD	Exploration Systems Mission Directorate
FRR	Flight Readiness Review
GEO	Geosynchronous Earth Orbit
ITAR	International Traffic In Arms Regulations
kg	kilogram
km	kilometer
LEO	Low Earth Orbit
Li-Ion	Lithium Ion
m^2	Meters squared
ml	milliliter
mm	millimeter
N/A	Not Applicable.
ODAR	Orbital Debris Assessment Report
TechEdSat	Technical Education Satellite
ORR	Operations Readiness Review
OSMA	Office of Safety and Mission Assurance
PDR	Preliminary Design Review
PL	Payload
P-POD	Poly Picosatellite Orbital Deployer
PSIa	Pounds Per Square Inch, absolute
PSRR	Pre-Ship Readiness Review
RAAN	Right Ascension of the Ascending Node
SESLO	Space environment survivability of live organisms (payload)
SMA	Safety and Mission Assurance
Ti	Titanium
USAF	United States Air Force
UTJ	Ultra Triple Junction
yr	year

Appendix B: Battery Data Sheet

MATERIAL SAFETY DATA SHEET

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SECTION 1 IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY/UNDERTAKING

Product Name:	Lithium Ion Battery
Product Code:	BP-930
Company Name:	Canon Inc.
Address:	30-2, Shimomaruko 3-Chome, Ohta-ku, Tokyo 146-8501, Japan
Use of the Product:	Battery for Video camera
Supplier:	
Address:	
Phone number:	

With regard to air transport, the International Civil Aviation Organization (ICAO) Packing Instruction 965 Part 1 complies with the Recommendation as is; further, the International Air Transport Association (IATA) adopts ICAO Packing Instruction 965 Part 1. In addition, the regulations of the US Department of Transportation for land, sea and air transportation are based on the UN Recommendations.

SECTION 2 MATERIALS AND INGREDIENTS INFORMATION

IMPORT ANT NOTE: The battery pack uses four US 18650S lithium-ion rechargeable cells and control circuit on the PWB.
The cells are connected in 2 parallel strings of 2 cells in series.
The battery pack should not be opened or burned since the following ingredients contained within the cells could be harmful under some circumstance if exposed or misused.
The cells contain neither metallic lithium nor lithium alloy.

Cathode:	Lithium-Cobalt Dioxides	(active material)
	Polyvinyldiene Fluoride	(binder)
	Graphite	(conductive material)
Anode:	Graphite	(active material)
	Polyvinyldiene Fluoride	(binder)
Electrolyte:	Organic Solvent	(non-aqueous liquid)
	Lithium Salt	
Others:	Heavy metals such as Mercury, Cadmium, Lead, and Chromium are not used in the cells.	
Enclosure:	Plastic (PC)	

SECTION 3 FIRE HAZARD DATA

In case of fire, use CO_2 or dry chemical extinguishers.

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SECTION 4 HEALTH HAZARD DATA

Under normal condition of use, these chemicals are contained in sealed can. Risk of exposure occurs only if the cells are mechanically abused.

Inhalation:	Contents of an opened cell can cause respiratory irritation.
	Remove to fresh air immediately and call a doctor.
Skin Contact:	Contents of an opened cell can cause skin irritation.
	Wash skin with soap and water.
Eye Contact:	Contents of an opened cell can cause eye irritation.
	Immediately flush eyes thoroughly with water for at least 15 minutes. Seek medical attention.

SECTION 5 PRECAUTIONS FOR SAFE HANDLING AND USE

Storage:	Store within the recommended limit of -20 degrees C to 45 degrees C (-4 degrees F to 113 degrees F), well-ventilated area. Do not expose to high temperature (60 degrees C/140 degrees F). Since short circuit can cause burn hazard or safety vent to open, do not store with metal jewelry, metal covered tables, or metal belt.
Handling:	Do not disassemble, remodel, or solder. Do not short + and - terminals with a metal. Do not open the battery pack.
Charging:	Charge within the limits of 0 degrees C to 40 degrees C (32 degrees F to 104 degrees F) temperature.
	Charge with specified charger designed for this battery pack.
Discharging:	Discharge within the limits of -10 degrees C to 50 degrees C (14 degrees F to 122 degrees F) temperature.
Disposal:	Dispose in accordance with applicable federal, state and local regulation.
Caution:	Attach the cover to the battery pack to prevent short circuits.
	Do not disassemble. Do not incinerate. Do not expose to temperature above 140 degrees F.

SECTION 6 SPECIAL PROTECTION INFORMATION

Respiratory Protection:	Not necessary under normal use.
Ventilation:	Not necessary under normal use.
Eye Protection:	Not necessary under normal use.
Protective Gloves:	Not necessary under normal use.

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Appendix C: Wiring Schematics