TSat Summary Orbital Debris Assessment Report

(ODAR)

Summary Revision 1

May 2, 2013

DAS Software Used in This Analysis: DAS V2.0.2

Record of Revisions

Revision	Date	Pages	Description	Author

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Self-assessment of the ODAR using the format in the 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: TSat Mission

Requirement	**Compliance Assessment**	**Comments**
4.3-1a	Compliant	No-planned debris release
4.3-1b	Compliant	No-planned debris release
4.3-2	Compliant	No-planned debris release
4.4-1	Compliant	On-board energy source (batteries) incapable of debris producing failure
4.4-2	Compliant	On-board energy source (batteries) incapable of debris producing failure
4.4-3	Compliant	No-planned breakups
4.4-4	Compliant	No-planned breakups
4.5-1	Compliant	
4.5-2	Compliant	
4.6-1(a)	Compliant	
4.6-1(b)	Compliant	
4.6-1(c)	Compliant	
4.6-2	Compliant	
4.6-3	Compliant	
4.6-4	Compliant	
4.6-5	Compliant	
4.7-1	Compliant	Non-credible risk of human casualty
4.8-1	Compliant	

ODAR Section 1: Program Management and Mission Overview

Project Manager: Prof. Sara Seager

Key Personnel: Alessandra Babuscia, Mary Knapp, Prof. Paulo Lozano, Fernando Mier Hicks, Mark Van de Loo

Foreign Government or Space Agency Participation: none.

Launch: Spring 2014

Schedule of Mission Milestones:

Engineering unit designed	December 2012
Vacuum tests of engineering unit	March 2013
Fcc application filed	March 2013
Flight unit integration and tests	November 2013
Deliver of flight unit to launch provider	February 2014
Launch and beginning of operations	April 2014

Mission Overview:

TSat is a 1U CubeSat (10x10x10 cm, 1.4Kg mass) developed at MIT to test electrospray micropropulsion (ESMP) thrusters. During the mission, TSat will perform tasks in increasing order of complexity: initially the correct functionality of the thruster will be assessed through current and voltage measurements. Then, simple maneuvers will demonstrate the ability of TSat to control its attitude and pointing. Finally, TSat will perform a controlled de-orbit.
The ESMP thrusters provide high efficiency and high I_{sp} (2500 to ~3500 seconds depending on propellant) propulsion in very small packages. Figure 1 shows prototypes of thruster modules (each module is about 1 cm^2, < 3 mm thick). The propellant is fed passively by capillarity through the porous substrate. No pressurized tanks nor valves and plumbing are required and the thrusters can be integrated in simple and small assemblies. The working principle is based on the electrostatic extraction and acceleration of heavy molecular ions directly from the surface of an extremely low vapor-pressure ionic liquid.

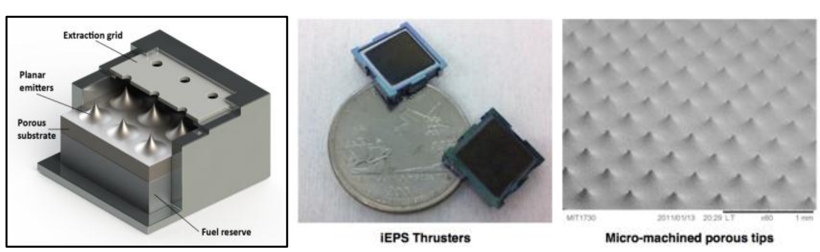

Figure 1: Thruster components (left), thruster assemblies with US quarter for scale (center), microscope image of micromachined porous emitter tips (right)

TSat will communicate to the ground using a UHF transceiver and antenna at the central frequency of 437 MHz. The dimensions of the spacecraft are consistent with CubeSat and P-POD standards. It is a single unit with the dimensions of 10 cm X 10 cm X 10 cm. The total mass is about 1.4 kg. The estimated mission duration is up to 1 year.
The satellite will be launched in Spring 2014. A launch was procured through NanoRacks. NanoRacks launches are accomplished using a deployer similar to the P-POD, but the CubeSats are released from International Space Station via the Kibu airlock. NanoRacks will assist the TSat team in ensuring that the satellite respects all the safety requirements for the ISS and it will guide the team in all the necessary steps up to launch.
Since the CubeSat will be released from the International Space Station. Hence, the initial orbit is defined as follows:

Apogee: 424 Km
Perigee: 402 Km
Inclination: 51 deg

TSat will end its mission by performing a controlled de-orbit.

ODAR Section 2: Spacecraft Description

The CubeSat is a 1U CubeSat, shown in Figure 2, will carry the ESMP thrusters on two sides of the spacecraft. The dimensions are 10cmx10cmx10cm and the mass is 1.4 Kg.

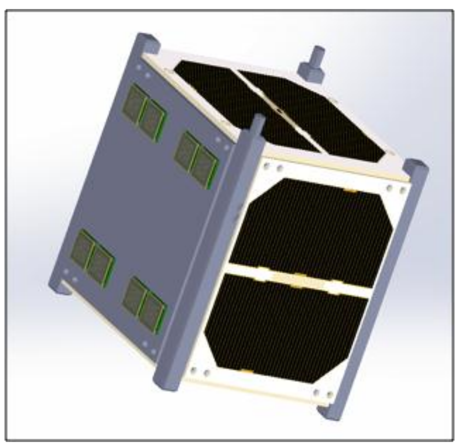

Figure 2: TSat CAD model. Four sides of the 1U CubeSat hold solar panels. The remaining two panels contain thrusters.

The main characteristics of the subsystems are summarized as follows:

- **Avionics:** The flight avionics system is composed primarily of the GomSpace NanoMind 712 C avionic board (ARM 7 processor, FreeRTOS OS, 2GB storage in the SD card, built-in magnetometer, CAN and I2C interfaces).
- **Power:** The NanoPowerPack 1U produced by GomSpace will power TSat. The NanoPowerPack bundle includes an electric power distribution unit (photovoltaic power conversion up to 30 W, 2 regulated power buses at 3 V and 5.5 V, and battery capacity of 1800 or 2600 mAh), 4 solar panels (each composed of 2 triple junction GaAs cells at

28% efficiency), and 2 Li-Ion batteries. Three of the solar panels carry a coarse sun sensor, a magnetorquer, and a rate-tracking gyro.

- **Communications**: The satellite will communicate to the ground (MIT UHF station) using a UHF link. The system includes a COTS (Commercial-Off-The-Shelf) modem from Radiometrix and the GomSpace UHF antenna system composed of 4 monopole antennas.
- **Attitude Determination and Control System (ADCS):** The attitude sensors (magnetometer, gyros, sun sensors) are already integrated into the avionics and power system PCBs. The actuation commanded by the control law will be performed by the thrusters. Torque coils built into the solar panels will provide a back-up actuation system.
- **Structure:** The structure will be the standard 1U CubeSat structure compatible with the Cal Poly standard.
- **Propulsion payload:** Sixteen ESMP thruster units will be placed on two opposite sides of the spacecraft.

During the mission, TSat will perform different tasks in increasing order of complexity: initially the correct functionality of the thruster will be assessed through current and voltage measurements. After that, simple maneuvers will demonstrate the ability of TSat to control its attitude and pointing. Finally, the thrusters will be used to test the capability of TSat to perform a controlled de-orbit.

Tracking of the orbital trajectory using ground-based tracking and communications passes will allow our team to estimate the effectiveness of translational maneuvers when operating the thrusters in the main propulsion mode (i.e., by tracking changes in the orbital elements). Over the mission lifetime, the data collected would be combined to obtain the time history of thruster efficiency, specific impulse, thrust and assess system degradation. Telemetry will be received at MIT through the use of the MIT UHF ground station communication system owned by MIT Radio Club.

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

The assessment of spacecraft debris requires the identification of any object (>1 mm) expected to be released from the spacecraft any time after launch, including object dimensions, mass, and material. This section requires rationale/necessity for release of each object, time of release of each object, relative to launch time, release velocity of each object with respect to spacecraft, expected orbital parameters (apogee, perigee, and inclination) of each object after release, calculated orbital lifetime of each object, including time spent in Low Earth Orbit (LEO), and an assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2. No objects will be intentionally released from the spacecraft during normal operation therefore this section is not applicable.

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 f or 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 batteries are four lithium-ion batteries (energy 27 Wh), manufactured by GomSpace. The batteries have extensive flight heritage because they have been already used on the AAUSAT CubeSat mission. See below for a description of the combined faults that could lead to a battery explosion and related mitigation techniques.

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:
TSat will perform a controlled de-orbit as part of its mission. 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: 0.0001.

Rationale:
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 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 faults must occur for each failure mode to cause the explosion.

Failure mode 1: Battery Internal short circuit.
Mitigation 1: Flight heritage of the batteries on previous CubeSat missions (AAUSAT) and complete environmental tests of the battery at MIT: vibration, thermal and vacuum. The EPS system developed by GomSpace implements also low-high voltage protection as explained for failure mode 3.
Combined faults required for realized failure: all the tests must be ineffective in discovery of the failure mode and the protection on the GomSpace EPS must not work properly.

Failure Mode 2: Battery temperature rise (internal or due to the environment).
Mitigation 2: Two temperature sensors with SPI interface are mounted just under each battery set to provide battery temperatures for housekeeping purposes. The power switch and the heater are implemented as high side switches with drivers (see GomSpace battery datasheet). Power output from the power switch are redundant high-rel solder connections located in the corner of the PCB. The graph below shows a test of the heater system of the standard batteries connected to the GomSpace electric power unit which will also be part of TSat power system. Operation is in vacuum with only a small thermal coupling to vacuum chamber. Ambient temperature of vacuum chamber if 23degC. Battery voltage is 7.4V and heater resistance is 10 Ohm:

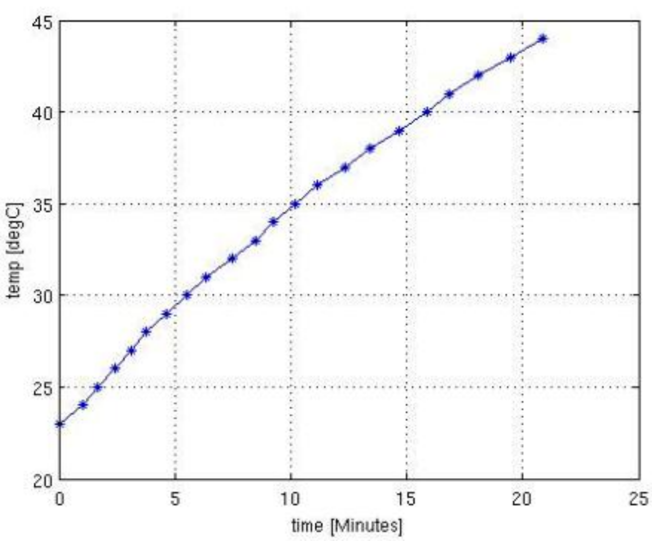

Figure 3: GomSpace batteries data (from GomSpace datasheet).

Combined faults required for realized failure: All the GomSpace analysis must fail in identifying the thermal characteristics of the batteries and in diagnosing failures of the heater switch.

Failure Mode 3: Excessive low or high charging voltage.
Mitigation 3: The GomSpace EPS implement battery protection for both low and high voltage in hardware and software. Specifically:

- Low voltage protection: It is implemented in both hardware and software. Should the battery voltage drop below 6.5V, the EPS software will switch off all user outputs until the battery voltage has reached 6.75V. If the battery voltage should for some reason drop below 6.0V, the EPS hardware will switch off both power conditioning converters until the battery voltages has reached a level of 6.5V.
- High voltage protection: The high voltage protection is implemented both in hardware and software. If running either of the software power point methods, the algorithms implements a constant voltage charge scheme that will keep the battery at its maximum voltage while at the same time supping the users with the necessary power. If the hardware power point solution is running, a rippling constant voltage type solution is implemented in hardware.

Combined faults required for realized failure: All the hardware and software protection must fail.

Failure Mode 4: Overcharge or excessive discharge
Mitigation 4: The GomSpace batteries and EPS were extensively test by the company and were also flown on the AAUSAT mission. The hardware and software controls of the EPS can control overcharge and excessive discharge
Combined faults required for realized failure: All previous tests must have failed.

Failure Mode 5: Crushing
Mitigation 5: No movable parts in proximity of the batteries.
Combined faults required for realized failure: NA

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 cannot cause an explosion or deflagration large enough to release orbital debris or break up the spacecraft (Requirement 56450).

Compliance statement:
The TSat is planned to operate until de-orbiting. Therefore, no post-mission passivation will be performed, as the satellite will break up on re-entry at the end of the mission.
Therefore, the TSat batteries 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 f or 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: 0.000000; COMPLIANT.

Output

	Space Structure	Compliance Status	Collision Probability
CubeSat	Payload	Compliant	0.00000

Figure 4: Output of DAS model for Requirement 4.5-1

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

Messages

Requirement 4.5-2: Compliant

Figure 5: Output of DAS for Requirement 4.5-2.

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

6.1 Description of spacecraft disposal option selected: The satellite will perform control de-orbit using the thrusters

6.2 Plan for any spacecraft maneuvers required to accomplish postmission disposal: TSat will perform attitude control tests for the first 2-4 weeks of operation. Once all attitude control testing is complete, TSat will fire its thrusters in the anti-velocity direction to decrease the spacecraft's orbital energy. This powered de-orbit maneuver will continue until TSat's fuel is exhausted. As shown in Figure 6, this powered de-orbit will decrease TSat's time in orbit by over a month. If the thrusters fail during the de-orbit phase of the mission, TSat will decay naturally within 1 year (see Figure 6).

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

Spacecraft Mass: 1.4 kg

Cross-sectional Area: 0.01 m^2.

Area to mass ratio: 0.007 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.

Analysis:

The TSat satellite reentry is COMPLIANT using Method "a." TSat will perform a controlled de-orbit as shown in Figure 6. In case of completely failure of the thrusters, TSat will perform natural decay from the initial orbit (ISS orbit) and it will be COMPLIANT using Method "a" as shown in Figure 6.

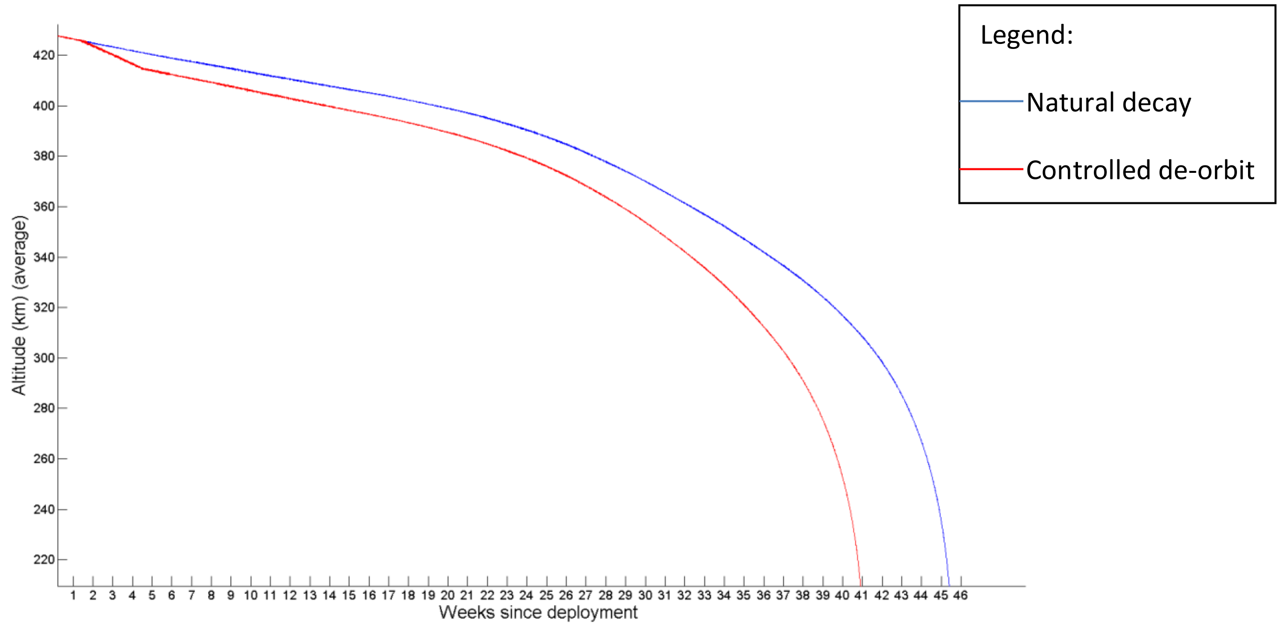

Figure 6: TSat decay: red line is the control de-orbit, while blue line is the natural decay.

Requirement 4.6-2: Disposal for space structures near GEO.
Analysis: Not applicable. TSat orbit is LEO.

Requirement 4.6-3: Disposal for space structures between LEO and GEO
Analysis: Not applicable. TSat orbit is LEO.

Requirement 4.6-4: Reliability of Postmission Disposal Operations
Analysis: In case of failure of the thrusters TSat will still be able to decay in less than 25 years (Figure 6). Hence, TSat is compliant with this requirement.

ODAR Section 7: Assessment of Spacecraft Re-entry H a z a r ds

Requirement 4.7-1.a: 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

Analysis
The analysis shows that TSat is compliant with Requirement 4.7-1: the total debris casualty area is 0 m^2, and the total Kinetic Energy is 0 Joule. No portion of the spacecraft will survive re-entry.

Object Name	Compliance Status	Risk of Human Casualty	SubComponent Object	Demise Altitude (km)	Total Debris Casualty Area ...	Kinetic Energy (J)
TSat	Compliant	1:0			0.00	
			Batteries and EPS	75.8	0.00	0
			ESMP Thrusters	77.4	0.00	0
			Avionic PCB	77.5	0.00	0
			CubeSat Structure	77.4	0.00	0
			UHF modem	76.5	0.00	0
			Solar Panel	77.5	0.00	0
			GPS	77.7	0.00	0
			Monopole antenna	77.8	0.00	0
			Thruster Control Board	77.6	0.00	0
			Modem board	77.6	0.00	0

Figure 7: Output of DAS software for requirement 4.7-1.

Requirement 4.7-1.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).

Analysis
The analysis of Figure 7 shows the results in case of TSat performing an uncontrolled reentry. This case is the worst case scenario with respect to the controlled reentry. As it can be seen from the DAS analysis, the kinetic energy is zero and the breakup happens at higher altitude than 50 Km. Hence, this requirement is satisfied.

Requirement 4.7-1.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)

Analysis
The analysis (Figure 7) shows that the risk of casualty is zero even in case of complete failure of the controlled de-orbit, in which case the satellite will naturally decay. Hence, this requirement is satisfied.

ODAR Section 8: Assessment for Tether Missions

Since the CubeSat does not involve tether deployments Section 8's requirement 4.8-1 is not applicable.

Appendix A: Complete DAS 2.0.2 Log File

03 17 2013; 17:20:56PM Processing Requirement 4.3-1: Return Status : Not Run
=====================
No Project Data Available
=====================
=============== End of Requirement 4.3-1 ===============

03 17 2013; 17:20:58PM Processing Requirement 4.3-2: Return Status : Passed
=====================
No Project Data Available
=====================
=============== End of Requirement 4.3-2 ===============

03 17 2013; 17:21:01PM Requirement 4.4-3: Compliant
=============== End of Requirement 4.4-3 ===============

03 17 2013; 17:21:03PM Processing Requirement 4.5-1: Return Status : Passed
==============
Run Data
==============
INPUT
Space Structure Name = TSat
Space Structure Type = Payload
Perigee Altitude = 402.000000 (km)
Apogee Altitude = 424.000000 (km)
Inclination = 51.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
MeanAnomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.007000 (m^2/kg)
Start Year = 2014.000000 (yr)
Initial Mass = 1.400000 (kg)
Final Mass = 1.400000 (kg)
Duration = 1.000000 (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 MeanAnomaly = 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 17 2013; 17:21:05PM Requirement 4.5-2: Compliant

03 17 2013; 17:21:07PM Processing Requirement 4.6 Return Status: Passed
==============
Project Data
==============

INPUT
Space Structure Name = TSat
Space Structure Type = Payload
Perigee Altitude = 402.000000 (km)
Apogee Altitude = 424.000000 (km)
Inclination = 51.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
MeanAnomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.007000 (m^2/kg)
Start Year = 2014.000000 (yr)
Initial Mass = 1.400000 (kg)
Final Mass = 1.400000 (kg)
Duration = 1.000000 (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 MeanAnomaly = 0.000000 (deg)

OUTPUT
Suggested Perigee Altitude = 402.000000 (km)
Suggested Apogee Altitude = 424.000000 (km)
Returned Error Message = Reentry during mission (no PMD req.).
Released Year = 2014 (yr)
Requirement = 61
Compliance Status = Pass
==============
=============== End of Requirement 4.6 ===============

03 17 2013; 17:21:13PM *********Processing Requirement 4.7-1
Return Status : Passed

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

name = TSat
quantity = 1
parent = 0
materialID = 7
type = Box
Aero Mass = 1.400000
Thermal Mass = 1.400000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.100000
name = Batteries and EPS
quantity = 1
parent = 1
materialID = -1
type = Box
Aero Mass = 0.250000
Thermal Mass = 0.250000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.020000
name = ESMP Thrusters
quantity = 16
parent = 1
materialID = 7
type = Box
Aero Mass = 0.001000
Thermal Mass = 0.001000
Diameter/Width = 0.010000
Length = 0.010000
Height = 0.010000
name = Avionic PCB
quantity = 1
parent = 1
materialID = 50
type = Box
Aero Mass = 0.055000
Thermal Mass = 0.055000
Diameter/Width = 0.090000
Length = 0.090000
Height = 0.010000
name = CubeSat Structure
quantity = 6
parent = 1
materialID = 7
type = Box
Aero Mass = 0.020000
Thermal Mass = 0.020000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.001000
name = UHF modem
quantity = 1
parent = 1

materialID = 50
type = Box
Aero Mass = 0.200000
Thermal Mass = 0.200000
Diameter/Width = 0.050000
Length = 0.100000
Height = 0.030000
name = Solar Panel
quantity = 6
parent = 1
materialID = 50
type = Box
Aero Mass = 0.060000
Thermal Mass = 0.060000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.005000
name = GPS
quantity = 1
parent = 1
materialID = 50
type = Box
Aero Mass = 0.020000
Thermal Mass = 0.020000
Diameter/Width = 0.045000
Length = 0.070000
Height = 0.010000
name = Monopole antenna
quantity = 1
parent = 1
materialID = 50
type = Box
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.003000
name = Thruster Control Board
quantity = 1
parent = 1
materialID = 50
type = Box
Aero Mass = 0.055000
Thermal Mass = 0.055000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.004000
name = Modem board
quantity = 1
parent = 1
materialID = 50
type = Box
Aero Mass = 0.055000

Thermal Mass = 0.055000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.004000

**************OUTPUT****
Item Number = 1
name = TSat
Demise Altitude = 77.999097
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Batteries and EPS
Demise Altitude = 75.761386
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = ESMP Thrusters
Demise Altitude = 77.386551
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Avionic PCB
Demise Altitude = 77.528558
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = CubeSat Structure
Demise Altitude = 77.437183
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = UHF modem
Demise Altitude = 76.485043
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Solar Panel
Demise Altitude = 77.529011
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = GPS
Demise Altitude = 77.688340
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Monopole antenna
Demise Altitude = 77.758160
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Thruster Control Board

Demise Altitude = 77.567355
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Modem board
Demise Altitude = 77.567355
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
=============== End of Requirement 4.7-1 ===============