Dove-2 Orbital Debris Assessment Report (ODAR)

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

Report Version: 1.1, 02/23/2011

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

DAS Software Version Used In Analysis: v2.0.1

VERSION APPROVAL and/or FINAL APPROVAL*:

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CTO

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

Record of Revisions				
REV	**DATE**	**AFFECTED PAGES**	**DESCRIPTION OF CHANGE**	**AUTHOR (S)**
A	02/21/2012	All	Initial release	James Mason
B	02/23/2012	5, 6, 13	Updated orbit and lifetime analysis	James Mason

Table of Contents

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

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

Orbital Debris Self-Assessment Report Evaluation: Dove-2 Mission

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

Notes:

1. The primary payload belongs to Roscosmos. This is not a Cosmogia primary mission. All of the other portions of the launch stack are non-Cosmogia and Dove-2 is not the lead.

Assessment Report Format:

ODAR Technical Sections Format Requirements:

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

Dove-2

ODAR Section 1: Program Management and Mission Overview

Project Manager: Chris Boshuizen

Foreign government or space agency participation: None.

Schedule of upcoming mission milestones:

FRR:	July 2012
Launch:	August 31, 2012

Mission Overview:
The Dove 2 mission is an internal company technology demonstration experiment to test the capabilities of a low-cost spacecraft constrained to the 3U cubesat form factor to host a small payload.

Dove 2 will do this by transmitting health and payload data to the ground. The payload data consists of image data taken from an on board nadir pointing camera. The images will be downlinked over the ISM frequency band at 2.4 GHz and the earth observation frequency band at 8.2 GHz.

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 33 cm. The total mass is about 5.8kg. The estimated mission duration is up to 181 days in orbit but we request a one year FCC license to be conservative.

Launch vehicle and launch site: Soyuz-2.1b, Baikonur/Tyuratam, Kazakhstan

Proposed launch date: 08/31/2012

Mission duration: 139-181 days in LEO operations until reentry via atmospheric orbital decay.

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

The Soyuz-2.1b will launch into a highly elliptical orbit. Once the final stage has burned out, the secondary payloads will be dispensed. After the secondary payloads are clear, the primary payload will separate. The primary payload is the Russian Bion-M biological research satellite. All payloads will re-enter in less than a year.

The Dove-2 satellite will deploy to, and decay naturally from, an elliptical orbit defined as follows:

Apogee: 290 km

Perigee: 575 km

Inclination: 64.9 degrees.

Dove-2 has no propulsion and therefore does not actively change orbits. There is no parking or transfer orbit.

ODAR Section 2: Spacecraft Description

Physical description of the spacecraft:

Dove-2 is based on the 3U cubesat form factor. The design mass is 5.8 kg. Basic physical dimensions are 100mm x 100mm x 340mm, with four 100mm x 300mm deployable solar arrays.

The Dove-2 superstructure is custom built by the Cosmogia team. The load bearing structure is basically comprised of three 100mm x 100mm skeleton plates, with L rails along each 300mm corner edge. Four 100mm x 300mm solar arrays are spring-loaded to deploy from camera end of the satellite, in a "dart" configuration.

Power storage is provided by Lithium-Ion cells. The batteries will be recharged by solar cells mounted on the body of the satellite and on the four deployable solar panels.

Dove-2 attitude is approximately determined using the magnetic field vector from the onboard magnetometers. Dove-2's attitude will be controlled by a B-dot controller, comprised of 3 air-core coil magnetorquers, and a gravity gradient boom to allow passive stabilization.

The communication subsystem consists of a S-band radio for two-way communication, an X band radio for downlink, and an Iridium modem for telemetry and commanding.

Total satellite mass at launch, including all propellants and fluids: ~5.8 kg.

Dry mass of satellites at launch, excluding solid rocket motor propellants: ~5.8 kg

Description of all propulsion systems (cold gas, mono-propellant, bi-propellant, electric, nuclear): None.

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: None

Fluids in Pressurized Batteries: None. Dove-2 uses unpressurized standard COTS Lithium-Ion battery cells. Each battery has a height of 64.6mm, a diameter of 13.9 and a weight of 26.0 grams.

Description of attitude control system and indication of the normal attitude of the spacecraft with respect to the velocity vector: Dove-2's attitude be controlled by a B-dot controller, comprised of 3 air-core coil magnetorquers, which will allow the satellite to be aligned relative to the Earth's magnetic field. These will allow the satellite to despin and 'lock' to the magnetic field. Additionally the satellite has an approximately 1-2m gravity gradient boom that will allow the satellite to be passively nadir-locked.

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

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

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 v2.0.1)

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

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

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

Potential causes of spacecraft breakup during deployment and mission operations:

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

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

In-mission failure of a battery cell protection circuit could lead to a short circuit resulting in overheating and a very remote possibility of battery cell explosion. The battery safety systems discussed in the FMEA (see requirement 4.4-1 below) describe the combined faults that must occur for any of seven (7) independent, mutually exclusive failure modes to lead to explosion. The deployment of the four solar arrays will feature an extremely simple spring and stopper system. The probability of a detachment during deployment is negligible.

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:

Due to short duration of the mission before passive reentry and burn up, the lithium-ion batteries (total mass of 208 grams) are deemed not necessary to passivate for EOM.

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

Requirement 4.4-1: Limiting the risk to other space systems from accidental explosions during deployment and mission operations while in orbit about Earth or the Moon:

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

Compliance statement:

Required Probability: 0.001.

Expected probability: 0.000.

Supporting Rationale and FMEA details:

Battery explosion:

Effect: All failure modes below might 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: Extremely 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). Additionally, the expected maximum satellite lifetime is less than 3 weeks - in the unlikely event of debris generation these objects will rapidly reenter.

Failure mode 1: Internal short circuit.
Mitigation 1: Qualification and acceptance shock, vibration, thermal cycling, and vacuum tests followed by maximum system rate-limited charge and discharge to prove that no internal short circuit sensitivity exists.
Combined faults required for realized failure: Environmental testing **AND** functional charge/discharge tests must both be ineffective in discovery of the failure mode.

Failure Mode 2: Internal thermal rise due to high load discharge rate.
Mitigation 2: Cells were tested in lab for high load discharge rates in a variety of flight like configurations to determine if the feasibility of an out of control thermal rise in the cell. Cells were also tested in a hot environment to test the upper limit of the cells capability. No failures were seen.
*Combined faults required for realized failure: S*pacecraft thermal design must be incorrect **AND** external over current detection and disconnect function must fail to enable this failure mode.

Failure Mode 3: Excessive discharge rate or short circuit due to external device failure or terminal contact with conductors not at battery voltage levels (due to abrasion or inadequate proximity separation).
Mitigation 4: This failure mode is negated by a) qualification tested short circuit protection on each external circuit, b) design of battery packs and insulators such that no contact with nearby board traces is possible without being caused by some other mechanical failure, c) obviation of such other mechanical failures by proto-

qualification and acceptance environmental tests (shock, vibration, thermal cycling, and thermal-vacuum tests).
Combined faults required for realized failure: An external load must fail/short-circuit **AND** external over-current detection and disconnect function must all occur to enable this failure mode.

Failure Mode 4: Inoperable vents.
Mitigation 5: Battery vents are not inhibited by the battery holder design or the spacecraft.
Combined effects required for realized failure: The final assembler fails to install proper venting.

Failure Mode 5: Crushing.
Mitigation 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 6: 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 7: 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** over-current monitoring and control must all fail for this failure mode to occur.

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

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

Compliance statement:
Dove-2's battery charge circuits include overcharge protection and a parallel design to limit the risk of battery failure. However, in the unlikely event that a battery cell does explosively rupture, the small size, mass, and potential energy, of these small batteries is such that while the spacecraft could be expected to vent gases, most debris from the battery rupture should be contained within the vessel due to the lack of penetration energy.

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 v2.0.1, 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: 0.00000; 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:** 0.00000; COMPLIANT
- **Identification of all systems or components required to accomplish any postmission disposal operation, including passivation and maneuvering:**

  None.

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: ~5.8kg

Cross-sectional Area: 0.07 m^2

Area to mass ratio: 0.07/5.8 = 0.012 m^2/kg

6.4 Assessment of spacecraft compliance with Requirements 4.6-1 through 4.6-5 (per DAS v 2.0.1 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 Dove-2 satellite's reentry is COMPLIANT using method “a.”. The Dove-2 will be left in a 295 km by 550 km orbit, reentering in less than 181 days after launch with orbit history as shown in Figure 1 (analysis assumes a nadir-pointing attitude).

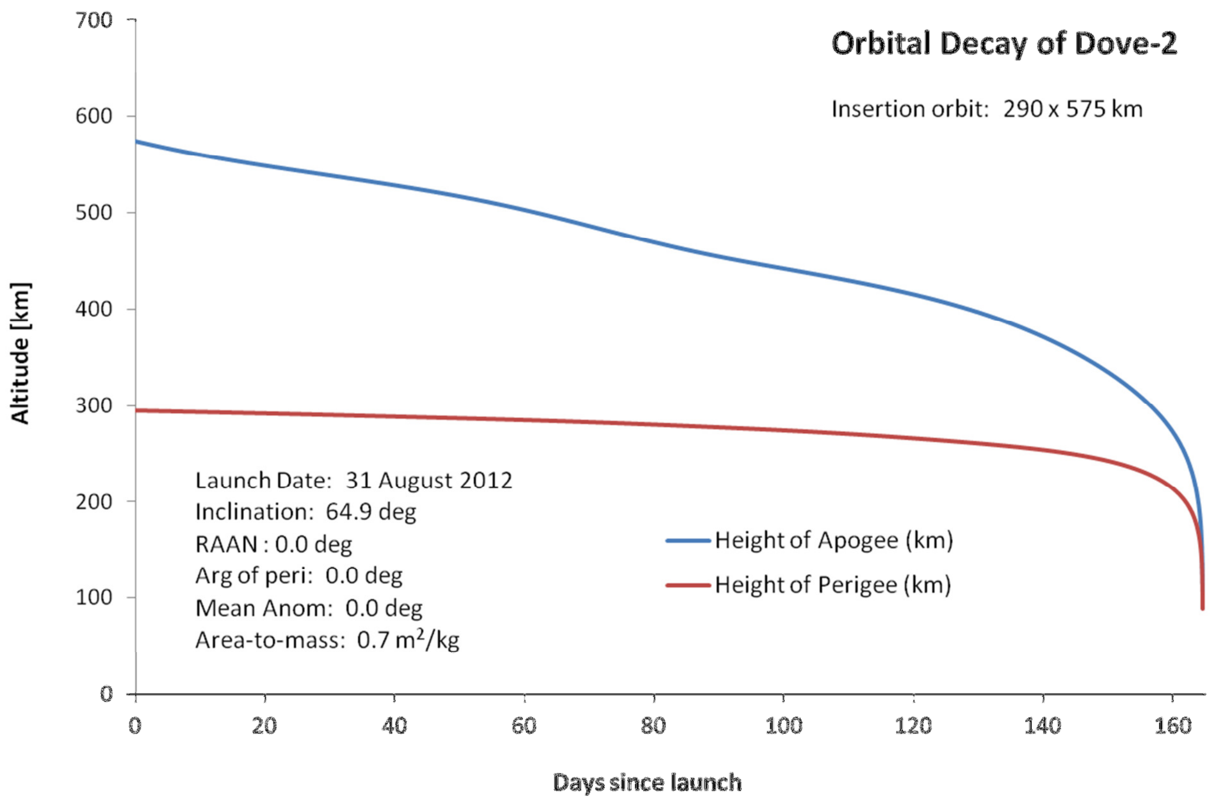

Figure 1: Dove-2 Orbit History

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

Analysis: Not applicable.

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

Analysis: Not applicable.

Requirement 4.6-4. Reliability of Postmission Disposal Operations

Analysis: Not applicable. The satellite will reenter passively without post mission disposal operations within allowable timeframe.

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 v2.0.1 reports that Dove-2 is compliant with the requirement. There is a low probability of the Invar telescope tube reaching the ground (see DAS input data below for input parameters). However, the DAS software does not allow explicit modeling of a thin cylindrical tube wall (inputs are cylinder shape and thermal mass), so these numbers are expected to be larger than anticipated. Total human casualty probability is reported by the DAS software as **1:154200.** This is expected to represent the absolute maximum casualty risk, as calculated with DAS's limited modeling capability.

Analysis (per DAS v2.0.1):

```
02 21 2012; 18:37:25PM  DAS Application Started
02 21 2012; 18:37:25PM  Opened Project C:\Documents and
Settings\Administrator\Desktop\das20\
02 21 2012; 18:37:45PM  Processing Requirement 4.3-1: Return Status :
Not Run

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

=============== End of Requirement 4.3-1 ===============
02 21 2012; 18:37:53PM  Processing Requirement 4.3-2: Return Status :
Passed

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

=============== End of Requirement 4.3-2 ===============
02 21 2012; 18:37:56PM  Requirement 4.4-3:  Compliant

=============== End of Requirement 4.4-3 ===============
02 21 2012; 18:37:59PM  Processing Requirement 4.5-1: Return Status :
Passed

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

**INPUT**
```

```
        Space Structure Name = Dove-2
        Space Structure Type = Payload
        Perigee Altitude = 290.000000 (km)
        Apogee Altitude = 575.000000 (km)
        Inclination = 64.900000 (deg)
        RAAN = 0.000000 (deg)
        Argument of Perigee = 0.000000 (deg)
        Mean Anomaly = 0.000000 (deg)
        Final Area-To-Mass Ratio = 0.0120000 (m^2/kg)
        Start Year = 2012.000000 (yr)
        Initial Mass = 5.8000000 (kg)
        Final Mass = 5.800000 (kg)
        Duration = 0.044000 (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 ===============
02 21 2012; 18:38:01PM  Requirement 4.5-2:  Compliant
02 21 2012; 18:38:03PM  Processing Requirement 4.6    Return Status :
Passed

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

**INPUT**

        Space Structure Name = Dove-2
        Space Structure Type = Payload

        Perigee Altitude = 295.000000 (km)
        Apogee Altitude = 550.000000 (km)
        Inclination = 65.000000 (deg)
        RAAN = 0.000000 (deg)
        Argument of Perigee = 0.000000 (deg)
        Mean Anomaly = 0.000000 (deg)
        Area-To-Mass Ratio = 0.075000 (m^2/kg)
        Start Year = 2012.000000 (yr)
        Initial Mass = 5.800000 (kg)
```

```
      Final Mass = 5.800000 (kg)
      Duration = 0.042000 (yr)
      Station Kept = False
      Abandoned = True
      PMD Perigee Altitude = 273.756382 (km)
      PMD Apogee Altitude = 400.214207 (km)
      PMD Inclination = 64.985690 (deg)
      PMD RAAN = 307.509517 (deg)
      PMD Argument of Perigee = 353.045620 (deg)
      PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

      Suggested Perigee Altitude = 273.756382 (km)
      Suggested Apogee Altitude = 400.214207 (km)
      Returned Error Message = Passes LEO reentry orbit criteria.

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

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

=============== End of Requirement 4.6 ===============
02 21 2012; 18:40:08PM  *********Processing Requirement 4.7-1
      Return Status :  Passed

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

name = Dove-2
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 5.800000
Thermal Mass = 5.800000
Diameter/Width = 0.100000
Length = 0.310000
Height = 0.100000

name = Tube
quantity = 1
parent = 1
materialID = 72
type = Cylinder
Aero Mass = 1.000000
Thermal Mass = 1.000000
Diameter/Width = 0.090000
Length = 0.200000

name = Avionics Box
quantity = 1
parent = 1
```

```
materialID = 5
type = Box
Aero Mass = 0.090000
Thermal Mass = 0.090000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.030000

name = Camera
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.500000
Thermal Mass = 0.500000
Diameter/Width = 0.080000
Length = 0.080000
Height = 0.080000

name = Batteries
quantity = 8
parent = 1
materialID = 46
type = Cylinder
Aero Mass = 0.046000
Thermal Mass = 0.046000
Diameter/Width = 0.018000
Length = 0.065000

name = DeployableArrays
quantity = 4
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.250000
Thermal Mass = 0.250000
Diameter/Width = 0.100000
Length = 0.300000

name = Structure
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.680000
Thermal Mass = 0.680000
Diameter/Width = 0.100000
Length = 0.300000
Height = 0.100000

name = Gradient Boom
quantity = 1
parent = 1
materialID = 8
```

```
type = Cylinder
Aero Mass = 0.700000
Thermal Mass = 0.700000
Diameter/Width = 0.020000
Length = 2.000000

name = SolarArrays
quantity = 4
parent = 1
materialID = 24
type = Flat Plate
Aero Mass = 0.150000
Thermal Mass = 0.150000
Diameter/Width = 0.100000
Length = 0.300000

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

name = Dove-2
Demise Altitude = 77.996355
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = TelescopeTube
Demise Altitude = 0.000000
Debris Casualty Area = 0.538997
Impact Kinetic Energy = 564.706421

*************************************
name = Avionics Box
Demise Altitude = 76.698746
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Camera
Demise Altitude = 72.261722
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Batteries
Demise Altitude = 72.041800
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = DeployableArrays
Demise Altitude = 76.199621
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
************************************
name = Structure
Demise Altitude = 75.842691
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Gradient Boom
Demise Altitude = 76.713176
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = SolarArrays
Demise Altitude = 77.651207
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 Dove-2 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 Dove-2 mission.

END of ODAR for Dove-2

Appendix A: Acronyms

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
FCC	Federal Communications Commission
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
PDR	Preliminary Design Review
PL	Payload
ISIPOD	ISIS CubeSat Deployer
PSIa	Pounds Per Square Inch, absolute
RAAN	Right Ascension of the Ascending Node
SMA	Safety and Mission Assurance
Ti	Titanium
USAF	United States Air Force
yr	year