December 21, 2012

Orbital Debris Assessment for the ORS Squared CubeSat on the ORS 4 Mission per NASA-STD 8719.14

Signature Page

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November 21, 2012

TO: Anthony Serafini, FCC

FROM: Craig Kief, COSMIAC

SUBJECT: Orbital Debris Assessment Report (ODAR) for the ORS Squared CubeSat

REFERENCES:

A. *NASA Procedural Requirements for Limiting Orbital Debris Generation*, NPR 8715.6A, 5 February 2008
B. *Process for Limiting Orbital Debris*, NASA-STD-8719.14, 28 August 2007
C. Reference Orbit Parameters for CSD Orbit on the ORS-4 Mission, [TBD]
D. McKissock, Barbara, Patricia Loyselle, and Elisa Vogel. *Guidelines on Lithium-ion Battery Use in Space Applications*. Tech. no. RP-08-75. NASA Glenn Research Center Cleveland, Ohio
E. *UL Standard for Safety for Lithium Batteries, UL 1642*. UL Standard. 4th ed. Northbrook, IL, Underwriters Laboratories, 2007
F. Range Safety User Requirements Manual Volume 3- Launch Vehicles, Payloads, and Ground Support Systems Requirements. AFSCM 91-710 V3.

The intent of this report is to satisfy the orbital debris requirements listed in ref. (a) for the ORS Squared auxiliary mission launching in conjunction with the ORS-4 primary payload. It serves as the final submittal in support of the spacecraft Safety and Mission Success Review (SMSR). Sections 1 through 8 of ref. (b) are addressed in this document; sections 9 through 14 falls under the requirements levied on the Department of Defense's Operationally Responsive Space Office and are not presented here.
The source file for the creation of this document is the ORS-3 ODAR Assessment Report.

The following table summarizes the compliance status of the ORS Squared auxiliary payload mission flown on ORS-4.

Table 1: ORS Squared Orbital Debris Requirement Compliance Matrix

Requirement	Compliance Assessment	Comments
4.3-1a	Not applicable	No planned debris release
4.3-1b	Not applicable	No planned debris release
4.3-2	Not applicable	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	Not applicable	No planned breakups
4.4-4	Not applicable	No planned breakups
4.5-1	Compliant	
4.5-2	Not applicable	
4.6-1(a)	Compliant	Worst case lifetime <2 yrs
4.6-1(b)	Not applicable	
4.6-1(c)	Not applicable	
4.6-2	Not applicable	
4.6-3	Not applicable	
4.6-4	Not applicable	Passive disposal
4.6-5	Compliant	
4.7-1	Compliant	Non-credible risk of human casualty
4.8-1	Not applicable	No tethers

Section 1: Program Management and Mission Overview

The ORS-4 mission is sponsored by the Operationally Responsive Space Office at Kirtland Air Force Base in New Mexico. The Program Executive is Jeff Welsh. Responsible program/project manager and senior scientific and management personnel are as follows:

ORS Squared Program Manager – Craig Kief, craig.kief@cosmiac.org
ORS Squared Principal Investigator – Jeremy Banik, Jeremy.Banik@kirtland.af.mil
ORS Squared Chief Engineer – Anders Karlsson, anders.karlsson@aacmicrotec.com

The ORS Squared payload timeline is shown in Appendix 1.

The ORS-4 mission will deploy a variety of different CubeSats. In addition, it will deploy a 6U CubeSat called ORS Squared. ORS Squared is 10cm x 20cm x 30cm and has a mass of 7 kilograms. ORS Squared will be ejected from a Canisterized Satellite Dispenser (CSD) in an orbit approximately 450x525km at 97.03 degrees inclination (ref. (c)).

Section 2: Spacecraft Description

There are six PPODs and one 6U (CSD) flying on the ORS-4 Mission. They are deployed out of the launch vehicle interface as shown in Figure 1.

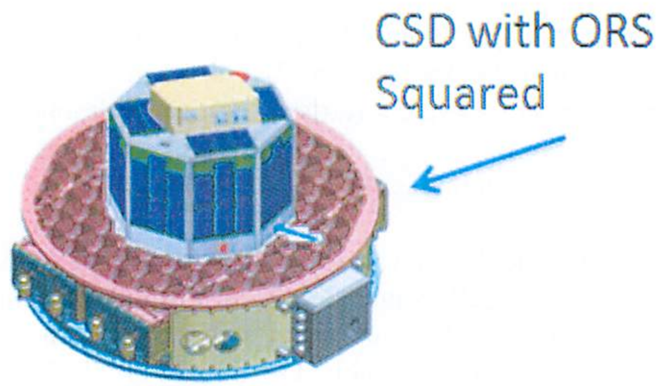


Figure 1. CSD and ORS Squared location

The following subsections contain a description of the ORS Squared CubeSat.

ORS Squared CubeSat Description

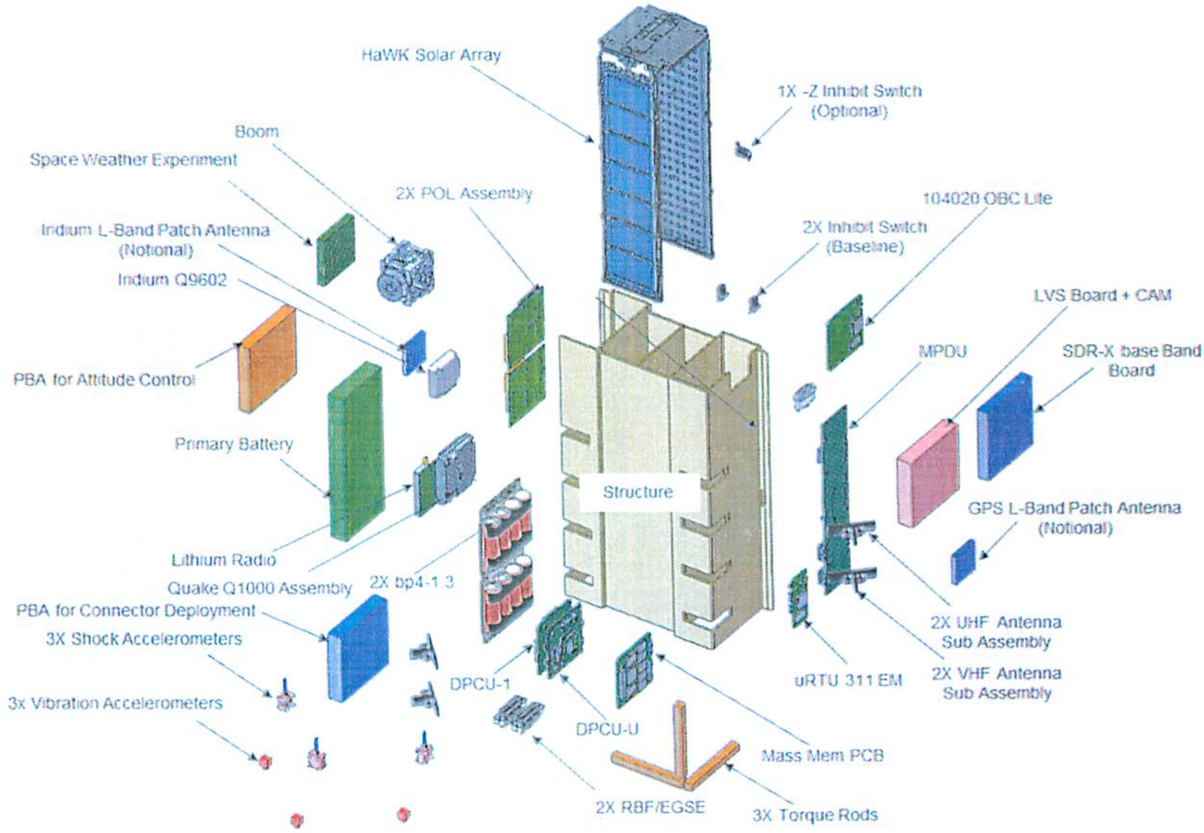


Figure 1: ORS Squared Expanded View

ORS Squared is a 6U CubeSat from the University of New Mexico. ORS Squared is a proof of concept flight for Space Plug-and-play Architecture (SPA). SPA is an open source bus architecture developed by the Air Force. In addition, the mission will fly a dosimeter for taking radiation measurements and a deployable solar power system.

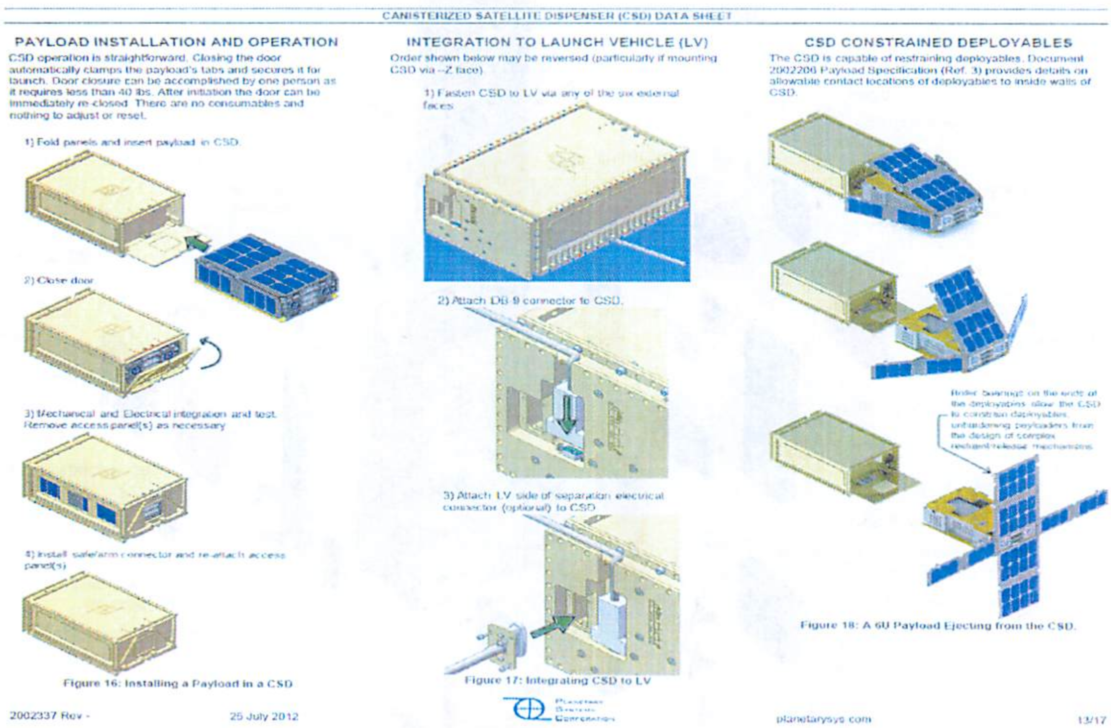
One hour after separation of the ORS Squared satellite from the CSD, the antennas, boom and solar system will be deployed and the beacon will be activated. For two weeks, contact will be attempted as well as differentiation between objects. For the next two years, experiments will be run with weekly data downloads. The experiments are planned to be run until deorbit.

The primary CubeSat structure is made of Aluminum Alloy 7075-T7. It contains all standard commercial off the shelf (COTS) materials, electrical components, PCBs and solar cells.

There are no pressure vessels, hazardous or exotic materials.

The electrical power storage system consists of common lithium-ion batteries with over-charge/current protection circuitry.

ORS Squared is built to conform to the overall onstraints shown in the corresponding CubeSat CSD specifications directly following.



CANISTERIZED SATELLITE DISPENSER (CSD) DATA SHEET

PAYLOAD INSTALLATION AND OPERATION

CSD operation is straightforward. Closing the door automatically clamps the payload's tabs and secures it for launch. Door closure can be accomplished by one person as it requires less than 40 lbs. After initiation the door can be immediately re-closed. There are no consumables and nothing to adjust or reset.

1) Fold panels and insert payload in CSD.

2) Close door

3) Mechanical and Electrical integration and test. Remove access panel(s) as necessary

4) Install safe/arm connector and re-attach access panel(s)

Figure 16: Installing a Payload in a CSD

INTEGRATION TO LAUNCH VEHICLE (LV)

Order shown below may be reversed (particularly if mounting CSD via –Z face)

1) Fasten CSD to LV via any of the six external faces

2) Attach DB-9 connector to CSD.

3) Attach LV side of separation electrical connector (optional) to CSD.

Figure 17: Integrating CSD to LV

CSD CONSTRAINED DEPLOYABLES

The CSD is capable of restraining deployables. Document 2002206 Payload Specification (Ref. 3) provides details on allowable contact locations of deployables to inside walls of CSD.

Roller bearings on the ends of the deployables allow the CSD to constrain deployables, unburdening payloaders from the design of complex restraint/release mechanisms.

Figure 18: A 6U Payload Ejecting from the CSD.

2002337 Rev -　25 July 2012　Planetary Systems Corporation　planetarysys.com　13/17

Figure 2: 6U CubeSat and CSD Specification

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.

Section 3 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 releases are planned on the ORS-4 ORS Squared CubeSat mission therefore this section is not applicable.

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

Note: This entire section applies to the batteries on the ORS Squared CubeSat on the ORS-4 mission.

A possible malfunction of Lithium ion or Lithium polymer batteries or of the control circuit has been identified as potential causes for spacecraft breakup during deployment and mission operations.

While no passivation of batteries will be attempted natural degradation of the solar cell and battery properties will occur over the post mission period, which may be as long as 2.5 years. These conditions pose a possible increased chance of the existence of several contributors to undesired battery energy release. The battery capacity for storage will degrade over time, possibly leading to changes in the acceptable charge rate for the cells. Individual cells may also change properties at different rates due to time degradation and temperature changes. The control circuit may also malfunction as a result of exposure over long periods of time. The cell pressure relief vents could be blocked by small contaminants. Any of these individual or combined effects may theoretically cause an electro-chemical reaction that result in rapid energy release in the form of combustion.

There are NO plans for designed spacecraft breakups, explosions, or intentional collisions on the ORS-4 mission.

Section 4 asks for a list of components which shall be passivized at End of Mission (EOM), as well as the method of passivation and description of the components which cannot be passivized. No passivation of components is planned at the End of Mission for ORS-4.

Rationale for all items which are required to be passivized, but cannot be due to their design is as follows. Since the batteries used do not present a debris generation hazard (see assessment directly below), passivation of the batteries is not necessary in order to meet the requirement 4.4-2 (56450) for passivation of energy sources "to a level which cannot cause an explosion or deflagration large enough to release orbital debris or break up the spacecraft." Because passivation is not necessary, and in the interest of not increasing the complexity of the CubeSats, there was no need to modify their electrical generation and storage systems.

Assessment of spacecraft compliance with Requirements 4.4-1 through 4.4-4 shows that the ORS Squared CubeSat is compliant. Requirements 4.4-3 and 4.4-4 are not applicable.

The following addresses requirement 4.4-2. The ORS Squared CubeSat that has been selected to fly on the ORS-4 mission has not been designed to disconnect their onboard storage energy devices (lithium ion and lithium polymer batteries). However, the CubeSat's batteries still meet Req. 56450 by virtue of the fact that they cannot "cause an explosion or deflagration large enough to release orbital debris or break up the spacecraft".

The batteries used in the ORS Squared CubeSat utilize lithium ion technology which are UL certified that shows compliance with UL Standard 1642. In general, these batteries are similar in size and power to cell phone batteries.

CubeSat	Technology	Manufacture	Model	UL Listing/Equivalent
ORS Squared	Li-Ion Polymer	VARTA	PLF503759	MH19896

Table 2: ORS-4 CubeSat Cells

The ORS Squared batteries are all consumer-oriented devices. They have been recognized as Underwriters Laboratories (UL) tested and approved. UL recognition has been determined through the UL Online Certifications Directory, which clearly shows that these one cell batteries have undergone and passed the UL Standards. Furthermore, safety devices incorporated in these batteries include pressure release valves, over current charge protection and over current discharge protection.

The fact that these batteries are UL recognized indicates that they have passed the UL standard testing procedures that characterize their explosive potential. Of particular concern to NASA Req. 56450 is UL Standard 1642, which specifically deals with the testing of lithium batteries. Section 20 Projectile Test of UL 1642 (ref. (e)) subjects the test battery to heat by flame while within an aluminum and steel wire mesh octagonal box, "[where the test battery] shall remain on the screen until it explodes or the cell or battery has ignited and burned out"(UL 1642 20.5). To pass the test, "no part of an exploding cell or battery shall penetrate the wire screen such that some or all of the cell or battery protrudes through the screen" (UL 1642 20.1).

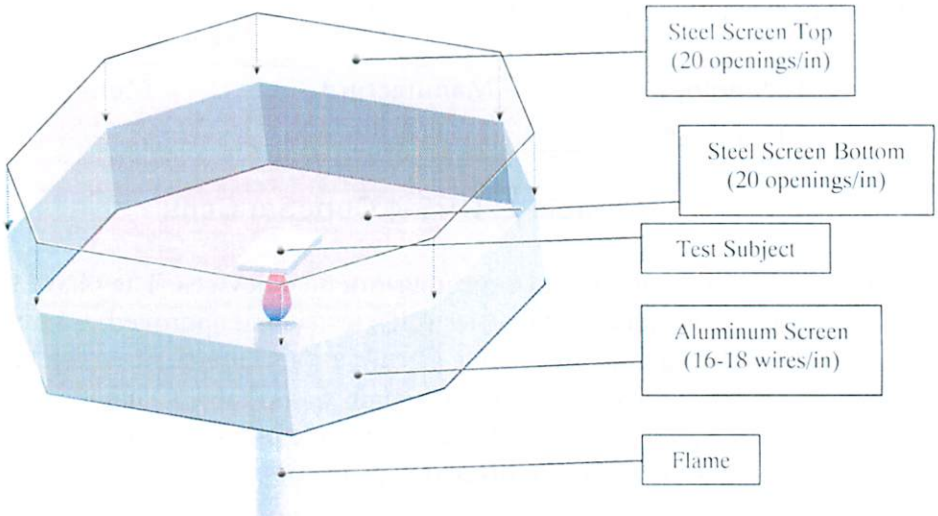


Figure 3: Underwriters Laboratory Explosion Test Apparatus

It is acceptable to expect the batteries being launched via this ORS mission to experience similar conditions during their orbital life span. While the source of failure would not be external heat on orbit, analysis of the expected mission thermal environment performed by NASA LSP Flight Analysis Division shows that given the very low (<=35 W-h, maximum for power dissipation for CubeSats, the batteries will be exposed to a maximum temperature that is well below their 212°F safe operation limit (ref. (f)). It is unlikely but possible that the continual charging with 2 to 6 W of average power from the solar panels over an orbital life span greater than 2 years may expose the batteries to overcharging which could cause similar heat to be generated internally. Through the UL recognition and testing, it has been shown that these batteries do not cause an explosion that would cause a fragmentation of the spacecraft.

A NASA Glenn Research Center guideline entitled Guidelines on Lithium-ion Battery Use in Space Applications (ref. (d)) explains that the hazards of Li-Ion cells in an overcharge situation result in the breakdown of the electrolyte found in Li-ion cells causing an increase internal pressure, formation of flammable organic solvents, and the release of oxygen from the metal oxide structure. From a structural point of view, a battery in an overcharge situation can expect breakage of cases, seals, mounting provisions, and internal components. The end result could be "unconstrained movement of the battery" (RP-08-75 pg 13). The relevant information to the NASA requirement being that only battery deformation and the escape of combustible gasses will be seen in an overcharging situation. It is important to note that the NASA guide to Li-ion batteries makes no mentions of the batteries causing explosions of any magnitude whatsoever.

Through a combination UL certification and an understanding of the general behavior of the failure modes associated with these types of batteries, it is possible to conclude that Requirement 56450 is satisfied. Specifically, these batteries will "not cause an explosion or deflagration large enough to release orbital debris or break up the spacecraft" (Requirement 56450).

Section 5: Assessment of Spacecraft Potential for On-Orbit Collisions

Calculation of spacecraft probability of collision with space objects larger than 10 cm in diameter during the orbital lifetime of the spacecraft takes into account both the mean cross sectional area and orbital lifetime.

The mean cross sectional area (CSA) for ORS Squared is approximately 30cm X 20cm X 40cm with the solar panels, two antennas and boom deployed. ORS Squared in a stowed configuration is 10cm X 20cm X 30cm:

$$Mean\ CSA = \frac{\sum Surface\ Area}{4} = \frac{[2 * (w * l) + 4 * (w * h)]}{4}$$

Equation 1: Mean Cross Sectional Area for Convex Objects

$$Mean\ CSA = \frac{(A_{max} + A_1 + A_1)}{2}$$

Equation 2: Mean Cross Sectional Area for Complex Objects

The CubeSat evaluated for this ODAR is stowed in a convex configuration, indicating there are no elements of the CubeSat obscuring another element of the same CubeSat from view. Thusly, the stowed CubeSat mean CSA was calculated using Equation 1.

Once ORS Squared has been ejected from the dispenser and deployables have been extended Equation 2 is utilized to determine the mean CSA. A_{max} is identified as the view that yields the maximum cross-sectional area. A_1 and A_2 are the two cross-sectional areas orthogonal to A_{max}.

The convex mean CSA for ORS Squared is 500 cm^2. The complex mean CSA is 1200 cm^2. Accordingly, DAS shows compliance with risk probability for collisions with large (and small) objects.

$$Convex\ Mean\ CSA = \frac{[2 * (20 * 30) + 4 * (20 * 10)]}{4} = 500cm^2$$

Equation 3: Mean Cross Sectional Area for Convex Objects

$$Complex\ Mean\ CSA = \frac{[(40 * 30) + (20 * 30) + (20 * 30)]}{2} = 1200cm^2$$

Equation 4: Mean Cross Sectional Area for Convex Objects

ORS Squared CubeSat

	Mass (kg)	7
Stowed	Mean C/S Area (m^2)	0.015
	Area-to Mass (m^2/kg)	0.013
	Orbital Lifetime (yrs)	2.2
	Probability of collision (10^X)	-7.7
Deployed	Mean C/S Area (m^2)	0.019
	Area-to Mass (m^2/kg)	0.016
	Orbital Lifetime (yrs)	1.7
	Probability of collision (10^X)	-7.8

Table 3: CubeSat Orbital Lifetime & Collision Probability

There will be no post-mission disposal operation. As such the identification of all systems and components required to accomplish post-mission disposal operation, including passivation and maneuvering, is not applicable.

Since the CubeSats have no capability or plan for end-of-mission disposal, requirement 4.5-2 is not applicable.

Assessment of spacecraft compliance with Requirements 4.5-1 shows ORS-4 to be compliant. Requirement 4.5-2 is not applicable to this mission.

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

The spacecraft will naturally decay from orbit within 25 years after end of the mission, satisfying requirement 4.6-1a detailing the spacecraft disposal option.

Planning for spacecraft maneuvers to accomplish post mission disposal is not applicable. Disposal is achieved via passive atmospheric reentry. The assessment of the spacecraft illustrates that ORS Squared is compliant with Requirements 4.6-1 through 4.6-5.

Section 7: Assessment of Spacecraft Reentry Hazards

ORS Squared satisfies the 4.7-1 Requirement, Reentry Debris Casualty Risk as determined by DAS using derived CubeSat dimensions. This assessment completes the summary of objects expected to survive an uncontrolled reentry, using NASA Debris Assessment Software (DAS), NASA Object Reentry Survival Analysis Tool (ORSAT), or comparable software

Probability calculations of human casualty for the expected year of uncontrolled reentry and the spacecraft orbital inclination show that there is no credible risk of human casualty. In the highly unlikely event that any object from a CubeSat does survive reentry, the necessarily small mass of the component along with the types of materials used in the CubeSats virtually ensure that the impact energy of the debris object will be less than 15 J. See assessment below.

ORS Squared does not plan for controlled reentry. No preliminary plan for spacecraft controlled reentry is provided.

Assessment of spacecraft compliance with Requirement 4.7-1 shows compliance. The total debris casualty area is zero. Casualty Expectation is zero. The following section addresses this requirement in detail.

The reentry risk for CubeSats can be assessed by doing analysis on bounding cases so as to determine what object size is required to reach the DCA limit and what kind of object properties (size, material, and mass distribution) can attain the 15 J impact energy threshold. Then the size and mass of these object cases can be evaluated relative to what is possible and/or realistic in terms of mass and size for an object or component that is part of the assembled 7 kg CubeSat system. Finally, the likelihood of violating both of the requirements simultaneously can also be assessed in terms of whether realistic scenarios that violate the DCA limit can be compatible with those that violate the 15 J threshold.

In the very unlikely event that a piece of debris or a fraction of a component object reaches the ground, the necessarily small mass of the component along with the types of materials used in the CubeSats (including ORS Squared) virtually ensure that the impact energy of the debris object will be less than 15 J. An analysis using DAS was conducted to determine the mass and size required for a component to reach Earth with energy greater than 15 J. This analysis shows that a titanium box shell the size of a CubeSat would require a mass of 0.14 kg, or 14% of the total CubeSat mass, in order to have an impact energy of 15 J. In addition, a solid titanium cylinder with a diameter of 1 cm, a length of 10 cm (the length of each side of the CubeSat) and a mass of .04 kg will also impact with 15 J. Components made of less durable materials such as those in ORS Squared will generally not survive at all. For example, a solid stainless steel rod 4 cm in diameter and 10 cm long, with a mass of 1 kg, will not reach the Earth's surface based on the DAS analysis.

When the bounding impact energy cases are combined with the casualty area assessment in the previous paragraph, it is clear that only under very specific circumstances would a CubeSat violate this requirement. Specifically, in order to violate this requirement, a CubeSat would have to be composed almost entirely of approximately 20 roughly equally-sized titanium components – fewer components would result in DCA that does not violate the casualty risk requirement, and more components would be too small to exceed the 15 J energy criteria due to the size and mass constraints placed on the CubeSat design.

In conclusion, violation of the subject criteria for a CubeSat mission such as ORS Squared is not credible, and it can be seen via inspection that the ORS Squared CubeSat addressed in this assessment do not reflect the types of design elements that would be required to produce a violation.

DAS v2.0 results shown below confirm that ORS Squared is compliant.

```
==============
Project Data
==============

**INPUT**

     Space Structure Name = ORS Squared
     Space Structure Type = Payload

     Perigee Altitude = 450.000000 (km)
     Apogee Altitude = 525.000000 (km)
     Inclination = 97.030000 (deg)
     RAAN = 0.000000 (deg)
     Argument of Perigee = 0.000000 (deg)
     Mean Anomaly = 0.000000 (deg)
     Area-To-Mass Ratio = 0.01714 (m^2/kg)
     Start Year = 2013.000000 (yr)
     Initial Mass = 7.000000 (kg)
     Final Mass = 7.000000 (kg)
     Duration = 1.000000 (yr)
     Station Kept = False
     Abandoned = True
     PMD Perigee Altitude = 367.602194 (km)
     PMD Apogee Altitude = 415.650398 (km)
     PMD Inclination = 97.039130 (deg)
     PMD RAAN = 349.686749 (deg)
     PMD Argument of Perigee = 101.908459 (deg)
     PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

     Suggested Perigee Altitude = 367.602194 (km)
     Suggested Apogee Altitude = 415.650398 (km)
     Returned Error Message = Passes LEO reentry orbit criteria.

     Released Year = 2014 (yr)
     Requirement = 61
     Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
12 21 2012; 12:04:37PM *********Processing Requirement 4.7-1
     Return Status :  Passed
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parent = 0
materialID = 9
type = Box
Aero Mass = 7.000000
Thermal Mass = 7.000000
Diameter/Width = 0.300000
Length = 0.300000
Height = 0.100000

name = AstroDev Radio
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.020000
Thermal Mass = 0.020000
Diameter/Width = 0.040000
Length = 0.040000
Height = 0.005000

name = OrbComm Radio
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.040000
Length = 0.040000
Height = 0.030000

name = Iridium Radio
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.033000
Length = 0.040000
Height = 0.020000

name = Software Radio
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.040000
Length = 0.044000
Height = 0.020000
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name = Antenna
quantity = 4
parent = 1
materialID = 5
type = Box
Aero Mass = 0.045000
Thermal Mass = 0.045000
Diameter/Width = 0.022000
Length = 0.045000
Height = 0.020000

name = Boom
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.102000
Thermal Mass = 0.052000
Diameter/Width = 0.040000
Length = 0.040000
Height = 0.020000

name = Magentometer
quantity = 1
parent = 7
materialID = 5
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.043000
Length = 0.047000
Height = 0.020000

name = Dosimeter
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.033000
Thermal Mass = 0.033000
Diameter/Width = 0.022000
Length = 0.040000
Height = 0.022000

name = GPS
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.055000
Thermal Mass = 0.055000
Diameter/Width = 0.044000
Length = 0.046000
Height = 0.012000

name = IMU
quantity = 1
parent = 1
```

```
materialID = 5
type = Box
Aero Mass = 0.070000
Thermal Mass = 0.070000
Diameter/Width = 0.045000
Length = 0.045000
Height = 0.030000

name = Master Control Board
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.043000
Length = 0.046000
Height = 0.023000

name = LVS System
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.394000
Thermal Mass = 0.044000
Diameter/Width = 0.046000
Length = 0.046000
Height = 0.020000

name = Sensors
quantity = 3
parent = 13
materialID = 5
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.040000
Length = 0.040000
Height = 0.020000

name = Cameras
quantity = 2
parent = 13
materialID = 5
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.040000
Length = 0.040000
Height = 0.020000

name = Camera Lens
quantity = 2
parent = 13
materialID = 5
type = Box
Aero Mass = 0.050000
```

```
Thermal Mass = 0.050000
Diameter/Width = 0.046000
Length = 0.046000
Height = 0.020000

name = Electrical Power System
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.590000
Thermal Mass = 0.050000
Diameter/Width = 0.050000
Length = 0.070000
Height = 0.020000

name = HaWK Solar Array
quantity = 1
parent = 17
materialID = 5
type = Box
Aero Mass = 0.080000
Thermal Mass = 0.080000
Diameter/Width = 0.046000
Length = 0.046000
Height = 0.020000

name = Battery Systems
quantity = 1
parent = 17
materialID = 5
type = Box
Aero Mass = 0.460000
Thermal Mass = 0.100000
Diameter/Width = 0.045000
Length = 0.048000
Height = 0.040000

name = LVS Battery
quantity = 2
parent = 19
materialID = 5
type = Box
Aero Mass = 0.080000
Thermal Mass = 0.080000
Diameter/Width = 0.047000
Length = 0.047000
Height = 0.020000

name = Main Battery
quantity = 4
parent = 19
materialID = 5
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.040000
Length = 0.040000
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```
Height = 0.020000

name = ADACs
quantity = 1
parent = 1
materialID = 5
type = Box
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Thermal Mass = 0.050000
Diameter/Width = 0.040000
Length = 0.040000
Height = 0.020000

**************OUTPUT****
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Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = AstroDev Radio
Demise Altitude = 76.072121
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = OrbComm Radio
Demise Altitude = 75.235144
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Iridium Radio
Demise Altitude = 74.554027
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Software Radio
Demise Altitude = 74.994043
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Antenna
Demise Altitude = 74.799738
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Boom
Demise Altitude = 74.822738
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
```

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name = Magentometer
Demise Altitude = 72.063472
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

***********************************
name = Dosimeter
Demise Altitude = 75.477097
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

***********************************
name = GPS
Demise Altitude = 74.414332
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

***********************************
name = IMU
Demise Altitude = 74.678480
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

***********************************
name = Master Control Board
Demise Altitude = 75.315621
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

***********************************
name = LVS System
Demise Altitude = 75.798988
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

***********************************
name = Sensors
Demise Altitude = 72.813894
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

***********************************
name = Cameras
Demise Altitude = 72.813894
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

***********************************
name = Camera Lens
Demise Altitude = 73.262230
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

***********************************
name = Electrical Power System
Demise Altitude = 76.350879
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
************************************
name = HaWK Solar Array
Demise Altitude = 72.333621
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Battery Systems
Demise Altitude = 73.130816
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = LVS Battery
Demise Altitude = 69.512972
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Main Battery
Demise Altitude = 70.373269
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = ADACs
Demise Altitude = 74.724035
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 ORS Squared 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).

Section 8: Assessment for Tether Missions

ORS Squared has no tethers so this section is not applicable.

Section 9-14

ODAR sections 9 through 14 for the launch vehicle are addressed in ref. (g), and are not covered here.

If you have any questions, please contact the undersigned at 505-934-1861.

/original signed by/

Craig Kief
COSMIAC, Deputy Director

Appendix A: Timeline