BroncoSat-1 Orbital Debris Assessment Report (ODAR)

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

Report Version: 1, 08/20/2020

Approved by:

Michael Pham

Michael Pham (Program Manager)

Prepared by:

Nathaniel Hebert

Nathaniel Hebert (Head Analyst of Laboratory)

Document Data is Not Restricted.

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

DAS Software Version Used In Analysis: v3.1

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: BroncoSat-1 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. This launch has several spacecraft manifested and BroncoSat-1 is not the primary mission

Assessment Report Format:

ODAR Technical Sections Format Requirements:

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 BroncoSat-1. Sections 9 through 14 apply to the launch platform, in this case the SpaceX Falcon 9, vehicle ODAR and are omitted.

ODAR Section 1: Program Management and Mission Overview

Project Manager: Bronco Space Club, Cal Poly Pomona

Foreign government or space agency participation: The satellite will deploy from a Momentus Vigoride vehicle, launched by SpaceX's Falcon 9 Launch Vehicle and will therefore involve only the United States private corporations.

Schedule of upcoming mission milestones:

Flight Readiness Review:	November 2nd
BroncoSat-1 Delivery to Momentus:	November 2020
Launch:	No Earlier Than February 2021

Mission Overview:
The BroncoSat-1 satellite will be ejected into a planned circular orbit of 450 x 450 km at 98 degrees. The satellite will then begin payload operations that will continue for up to 15 months.

ODAR Summary: No debris released in normal operations; no credible scenario for breakups; the collision probability with other objects is compliant with NASA standards; and the estimated nominal decay lifetime due to atmospheric drag is well under 25 years following operations (< 2 years, as calculated by DAS 3.1).

Launch vehicle and launch site: Falcon 9, Cape Canaveral

Proposed launch date: No Earlier Than February 2021

Mission duration: Nominal orbit lifetime: 11 months. Maximal orbit lifetime: 15 months

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

The BroncoSat-1 satellite will deploy from the Momentus Vigoride into a polar orbit from which it will naturally decay due to atmospheric drag. The deployment altitude depends on when the provider prefers to deploy, so the entire altitude range is considered.

***High Insertion Case*:**	**Apogee:** 475 km	**Perigee:** 475 km
***Low Insertion Case*:**	**Apogee:** 425 km	**Perigee:** 425 km

Inclination: 98 degrees

The BroncoSat-1 satellite 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:

The BroncoSat-1 satellite is a 1.5U CubeSat specification, with a launch mass of 1.75 kg. Overall physical dimensions are 100mm x 100mm x 170mm.

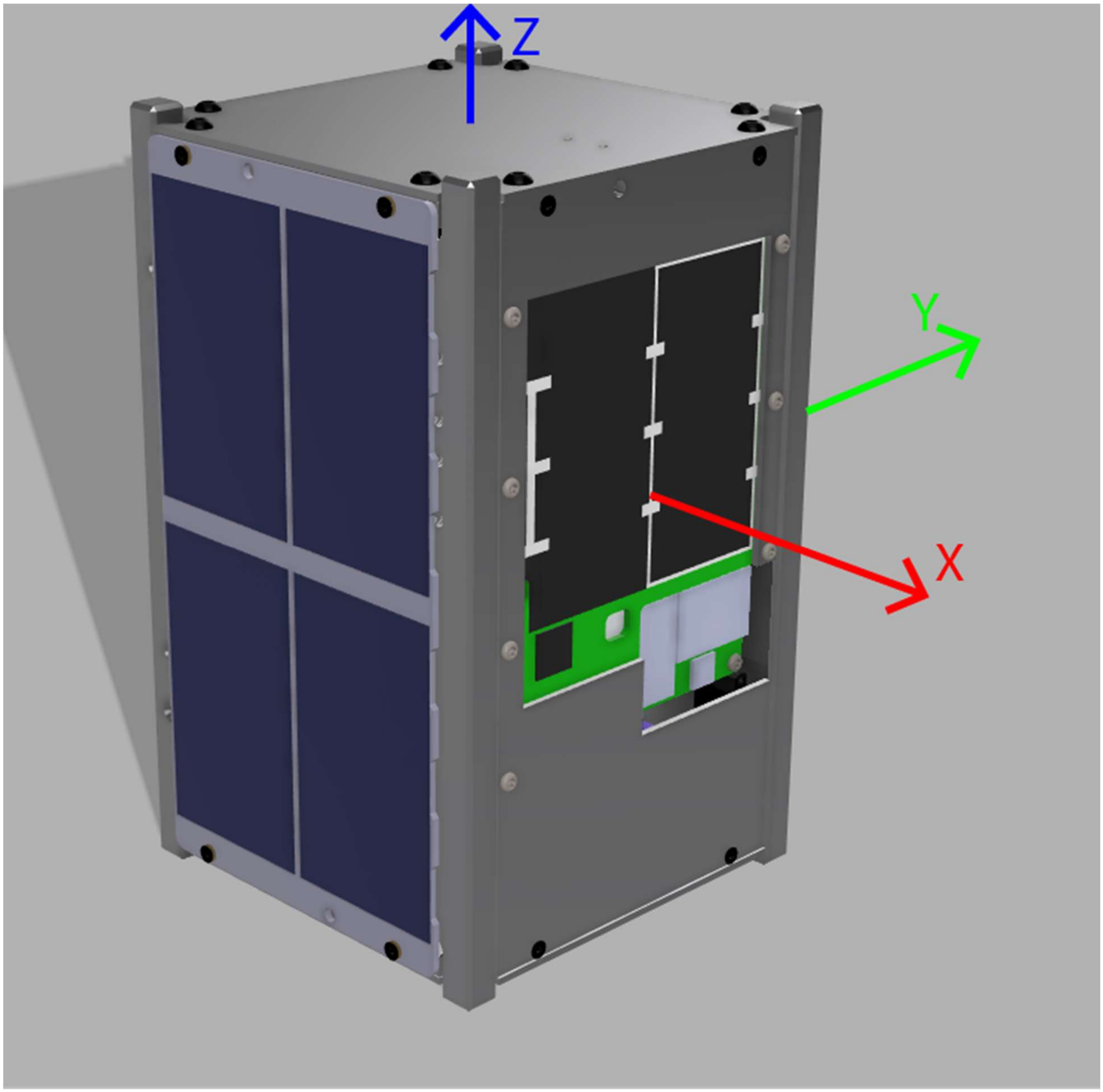


Figure 1 Rendering of the BroncoSat-1 Satellite

The load bearing structure is comprised of a frame made up of four individual parts: two on the side faces and two on the top and bottom. These incorporate the rails that interface with the deployer and mounting points for each of the exterior panels and internal boards. The solar panel arrays are mounted to three of the long faces on the frame of the satellite structure, while the remaining face parallel to the rails mounts the panel for the Near Space Launch Black Box unit. The top panel incorporates the switch for the remove before flight pin. The bottom panel mounts the antenna for the Duplex communications unit.

Power storage is provided by 6 Panasonic NCR18650B Lithium-Ion cells. The batteries will be recharged by solar cells mounted on the body of the satellite.

Total satellite mass at launch, including all propellants and fluids: 1.75 kg.

Dry mass of satellite at launch, excluding solid rocket motor propellants: 1.75 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. The satellite use unpressurized standard COTS Lithium-Ion battery cells. Each battery has a height of 65mm, a diameter of 18mm and a weight of 47.5 grams.

Description of attitude control system and indication of the normal attitude of the spacecraft with respect to the velocity vector:
Satellite attitude is controlled by three-axis magnetorquers. The nominal attitude will be the long axis (Z-axis) velocity-aligned, see Figure 1-B "low drag". A slight spin will be induced around the velocity vector for cooling and solar power. In de-orbit the spacecraft will be rotated into its long axis being NADIR pointing to increase drag within the high atmosphere, see Figure 1-A "high drag".

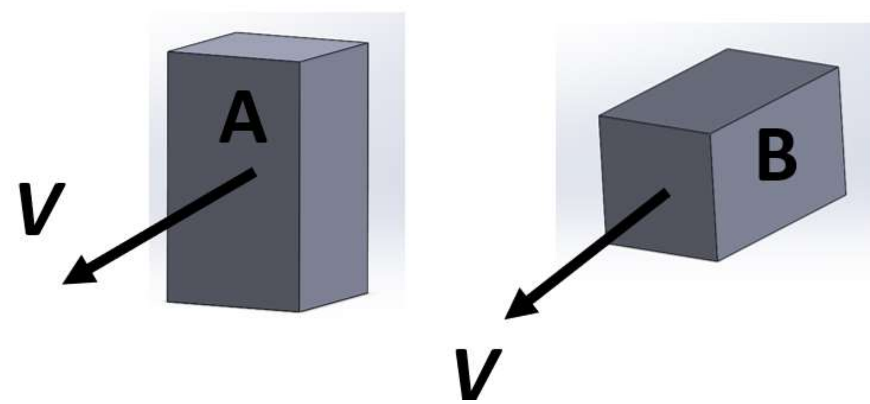


Figure 1: Attitude modes used in BroncoSat-1. A – high drag, B – low drag.

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. The cells are recharged by Spectrolab Gallium Arsenide Triple Junction solar cells mounted on the satellite's frame. A battery cell protection circuit manages the charging cycle, performs battery balancing, and protects against over and undercharge conditions.

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 v3.1)

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.

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. The 6 batteries will not be passivated at End of Mission due to the low risk and low impact of explosive rupturing, and the extremely short lifetime at mission conclusion. The maximum total chemical energy stored in each battery is ~10kJ.

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

<u>No items are required to be passivated.</u>

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:

Compliance statement:

Required Probability: 0.001.

Expected probability: 0.000.

Supporting Rationale and FMEA details:

Battery explosion:

Effect: All failure modes below might theoretically 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 the selected COTS 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 a much less than 0.1% probability that multiple independent (not common mode) faults must occur for each failure mode to cause the ultimate effect (explosion).

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 like likelihood and impact 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 3: 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) negation of risk 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 failure must all occur to enable this failure mode.

Failure Mode 4: Inoperable vents.
Mitigation 4: 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 on the spacecraft which may crush 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 failure modes 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 response for the spacecraft has been analyzed with simulated space environment temperatures showing that the batteries do not exceed normal allowable operating temperatures, which are well below temperatures of concern for explosions, during normal operation.
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:

Compliance statement:
The 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, 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 v3.1, 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:

Analysis Summary: BroncoSat-1 satellite is COMPLIANT as seen by the DAS analysis in Appendix-A.

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 post mission disposal requirements is less than 0.01 (Requirement 56507).

There are no critical components needed for reentry, as BroncoSat-1 will be utilizing passive reentry through atmospheric drag.

Identification of all systems or components required to accomplish any post mission disposal operation, including passivation and maneuvering:
None.

There are no critical components, therefore no probability of damage to critical components. Therefore the requirement is met.

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

6.1 Description of spacecraft disposal option selected: The satellite will de-orbit naturally by atmospheric re-entry within two years of deployment.

6.2 Plan for any spacecraft maneuvers required to accomplish postmission disposal:

Rapid atmospheric decay is ensured by the low initial altitude. The maximum expected orbital lifetime is 11 months. There are no plans to maneuver the satellite in order to facilitate de-orbit.

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

Spacecraft Mass: ~1.75 kg

Mean Cross-sectional Area: 0.022 m^2

Area to mass ratio: 0.0125 m^2/kg

6.4 Assessment of spacecraft compliance with Requirements 4.6-1 through 4.6-5 (per DAS v 3.1 and NASA-STD-8719.14 section):

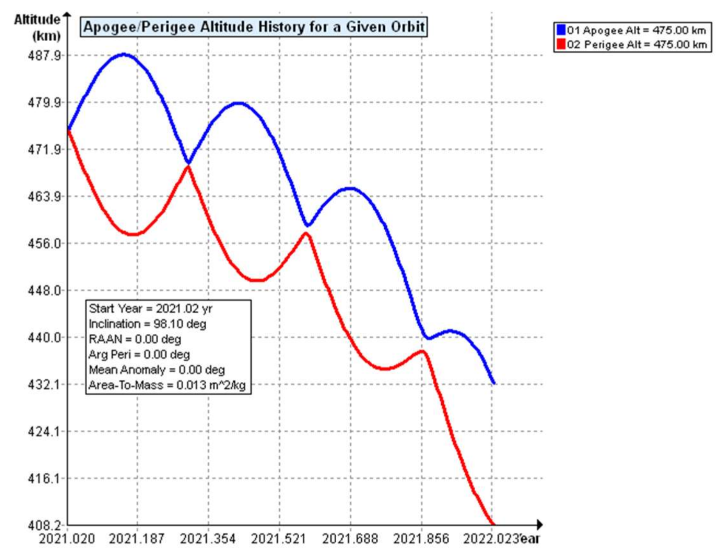
Requirement 4.6-1: Disposal for space structures passing through LEO:
A spacecraft or orbital stage with a perigee altitude below 2000 km shall be disposed of by one of three methods:
(Requirement 56557)
a. Atmospheric reentry option:

- *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*

Atmospheric reentry by natural orbit decay, is the option selected.
Analysis Summary: BroncoSat-1 satellite reentry is COMPLIANT using method "a" as seen by the below DAS generate plots and DAS analysis.

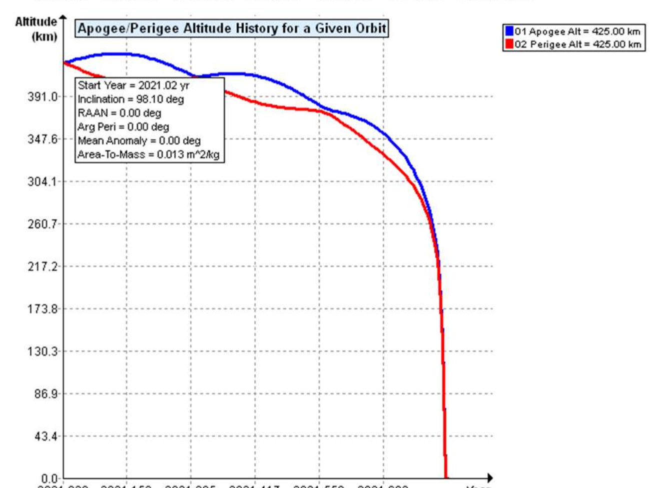
High Insertion Case

Satellite Name	BroncoSat-1
BOL "High" Orbit	475 × 475 km
Min Lifetime*	8 months
Max Lifetime*	15 months
Post-ops Life	< 1 week



Low Insertion Case

Satellite Name	BroncoSat-1
BOL "High" Orbit	425 × 425 km
Min Lifetime*	8 months
Max Lifetime*	15 months
Post-ops Life	< 1 week



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.

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:

Summary Analysis Results: Analysis performed using DAS v3.1 shows that no part of the satellite is expected to survive reentry, and therefore that the risk of human casualty is ~ 0. See Output Log in Appendix A.

Requirements 4.7-1b, and 4.7-1c below are non-applicable requirements because the BroncoSat-1 satellite do not use controlled reentry.

4.7-1, b) **NOT APPLICABLE. NO Controlled Reentry.** 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. NO Controlled Reentry.** 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 BroncoSat-1 mission.

END of ODAR for BroncoSat-1

Appendix A – DAS v3.1 Activity Log

08 07 2020; 15:17:26PM Activity Log Started
08 07 2020; 15:32:23PM Science and Engineering - Apogee/Perigee History for a Given Orbit

INPUT

Perigee Altitude = 425.000000 (km)
Apogee Altitude = 425.000000 (km)
Inclination = 98.00000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.012500 (m^2/kg)
Start Year = 2021.020000 (yr)
Integration Time = 1.000000 (yr)

OUTPUT

Plot
08 07 2020; 15:33:39PM Science and Engineering - Apogee/Perigee History for a Given Orbit

INPUT

Perigee Altitude = 425.000000 (km)
Apogee Altitude = 425.000000 (km)
Inclination = 98.00000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.012500 (m^2/kg)
Start Year = 2021.020000 (yr)
Integration Time = 1.000000 (yr)

OUTPUT

Plot
08 07 2020; 15:36:13PM Science and Engineering - Apogee/Perigee History for a Given Orbit

INPUT

Perigee Altitude = 475.000000 (km)
Apogee Altitude = 475.000000 (km)
Inclination = 98.00000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.012500 (m^2/kg)
Start Year = 2021.020000 (yr)
Integration Time = 1.000000 (yr)

OUTPUT

Plot
08 07 2020; 15:40:57PM Science and Engineering - Orbit Lifetime/Dwell Time

INPUT

Start Year = 2021.200000 (yr)
Perigee Altitude = 425.000000 (km)
Apogee Altitude = 425.000000 (km)
Inclination = 98.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.012500 (m^2/kg)

OUTPUT

Orbital Lifetime from Startyr = 0.678987 (yr)
Time Spent in LEO during Lifetime = 0.678987 (yr)
Last year of Propagation = 2021 (yr)
Returned Error Message: Object reentered

08 07 2020; 16:15:44PM Processing Requirement 4.3-2: Return Status : Passed

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

=============== End of Requirement 4.3-2 ===============

08 07 2020; 16:17:33PM Processing Requirement 4.5-1: Return Status : Passed

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

INPUT

Space Structure Name = Bronco Sat 1 LEO
Space Structure Type = Payload
Perigee Altitude = 450.000 (km)
Apogee Altitude = 450.000 (km)
Inclination = 98.000 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0125 (m^2/kg)
Start Year = 2021.200 (yr)
Initial Mass = 1.750 (kg)
Final Mass = 1.750 (kg)
Duration = 1.300 (yr)
Station-Kept = False
Abandoned = True

OUTPUT

Collision Probability = 2.4928E-08
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

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

=============== End of Requirement 4.5-1 ===============

08 07 2020; 16:21:51PM Project Data Saved To File
08 07 2020; 16:23:52PM Requirement 4.5-2: Compliant
08 07 2020; 16:23:57PM Processing Requirement 4.6 Return Status : Passed

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

INPUT

Space Structure Name = Bronco Sat 1 LEO
Space Structure Type = Payload

Perigee Altitude = 450.000000 (km)
Apogee Altitude = 450.000000 (km)
Inclination = 98.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.012500 (m^2/kg)
Start Year = 2021.200000 (yr)
Initial Mass = 1.750000 (kg)
Final Mass = 1.750000 (kg)
Duration = 1.300000 (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 = 450.000000 (km)
Suggested Apogee Altitude = 450.000000 (km)
Returned Error Message = Reentry during mission (no PMD req.).

Released Year = 2022 (yr)
Requirement = 61
Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
08 07 2020; 16:24:02PM Project Data Saved To File
08 07 2020; 22:03:51PM *********Processing Requirement 4.7-1
Return Status : Passed

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

name = Bronco Sat 1 LEO
quantity = 1
parent = 0
materialID = 8
type = Box
Aero Mass = 1.750000
Thermal Mass = 1.750000
Diameter/Width = 0.100000
Length = 0.170000
Height = 0.100000

name = Fasteners
quantity = 73
parent = 1
materialID = 54
type = Cylinder
Aero Mass = 0.004510
Thermal Mass = 0.004510
Diameter/Width = 0.030000
Length = 0.020000

name = Batteries
quantity = 6
parent = 1
materialID = 4
type = Cylinder
Aero Mass = 0.047500
Thermal Mass = 0.047500
Diameter/Width = 0.018000
Length = 0.065000

name = Solar Panels
quantity = 3
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.028800
Thermal Mass = 0.028800
Diameter/Width = 0.083000
Length = 0.160000

name = PyCubed Flight Computer
quantity = 1
parent = 1
materialID = 19
type = Flat Plate
Aero Mass = 0.030400
Thermal Mass = 0.030400
Diameter/Width = 0.100000
Length = 0.100000

name = Structure
quantity = 1

parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.385000
Thermal Mass = 0.385000
Diameter/Width = 0.100000
Length = 0.170000

name = Black Box
quantity = 1
parent = 1
materialID = 4
type = Flat Plate
Aero Mass = 0.140000
Thermal Mass = 0.140000
Diameter/Width = 0.100000
Length = 0.120000

name = Duplex
quantity = 1
parent = 1
materialID = 4
type = Flat Plate
Aero Mass = 0.138000
Thermal Mass = 0.138000
Diameter/Width = 0.100000
Length = 0.120000

name = Jetson Nano
quantity = 1
parent = 1
materialID = 4
type = Flat Plate
Aero Mass = 0.120000
Thermal Mass = 0.120000
Diameter/Width = 0.080000
Length = 0.100000

name = Magnetorquers
quantity = 1
parent = 1
materialID = 19
type = Cylinder
Aero Mass = 0.230000
Thermal Mass = 0.230000
Diameter/Width = 0.030000
Length = 0.060000

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

name = Bronco Sat 1 LEO
Demise Altitude = 77.999626
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****

name = Fasteners
Demise Altitude = 76.647263
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Batteries
Demise Altitude = 74.687683
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Solar Panels
Demise Altitude = 77.655540
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = PyCubed Flight Computer
Demise Altitude = 77.374718
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structure
Demise Altitude = 72.623901
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Black Box
Demise Altitude = 75.170769
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Duplex
Demise Altitude = 75.206764
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Jetson Nano
Demise Altitude = 74.746696
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Magnetorquers
Demise Altitude = 70.427040
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
============== End of Requirement 4.7-1 ==============
08 07 2020; 22:03:51PM Project Data Saved To File

Large Object Impact and Debris Generation Probability:

Analysis (per DAS v3.1):

```
08 07 2020; 15:04:19PM   Processing Requirement 4.5-1: Return Status
:  Passed

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

**INPUT**

     Space Structure Name = Bronco Sat 1 LEO
     Space Structure Type = Payload
     Perigee Altitude = 450.000 (km)
     Apogee Altitude = 450.000 (km)
     Inclination = 98.000 (deg)
     RAAN = 0.000 (deg)
     Argument of Perigee = 0.000 (deg)
     Mean Anomaly = 0.000 (deg)
     Final Area-To-Mass Ratio = 0.0125 (m^2/kg)
     Start Year = 2021.200 (yr)
     Initial Mass = 1.750 (kg)
     Final Mass = 1.750 (kg)
     Duration = 1.300 (yr)
     Station-Kept = False
     Abandoned = True

**OUTPUT**

     Collision Probability = 2.4928E-08
     Returned Message: Normal Processing
     Date Range Message: Normal Date Range
     Status = Pass

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

=============== End of Requirement 4.5-1 ===============
```