Conejo Demonstration

Orbital Debris Assessment Report (ODAR)

DAS Software v3.2.1

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

Jun 06, 2022

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Revision History

Revision	Date	Author(s)	Description
1.0	06/06/2022	DT	Initial Release

Contents

Self Assessment per NASA-STD-8719.14

List of Tables

List of Figures

Self-Assessment per NASA-STD-8719.14

A self-assessment in accordance with the format provided in Appendix A.2 of NASA-STD-8719.14 is shown below in Table 1.

Section	Status	Comment
4.3-1, Mission-Related Debris Passing Through LEO	Compliant	
4.3-2, Mission-Related Debris Passing Near GEO	N/A	
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	Compliant	
4.4-2, Design for passivation after completion of mission operations while in orbit about Earth or the Moon	Compliant	
4.4-3, Limiting the long-term risk to other space systems from planned breakup	Compliant	
4.4-4, Limiting the short-term risk to other space systems from planned breakup	Compliant	
4.5-2, Probability of Damage from Small Objects	Compliant	
4.6-1, Disposal for space structures passing through LEO	N/A	
4.6-2, Disposal for space structures passing through GEO	N/A	
4.6-3, Disposal for space structures between LEO and GEOs	N/A	
4.6-4, Reliability of post-mission disposal operations	Compliant	
4.7-1, Limit the risk of human casualty	Compliant	
4.8-1, Collision Hazards of Space Tether	N/A	

Table 1: Assessment Report Format

Assessment Report Format

Astro Digital US, Inc. is a U.S. company. This ODAR follows the format in NASA-STD-8719.14, Appendix A.1 and includes the content indicated as a minimum, in each of sections 2 through 8 below. Sections 9 through 14 apply to the launch vehicle ODAR and are not covered here.

1 Program Management and Mission Overview

Astro Digital
System Engineer: Philip Szerakowski
System Engineer: David Thorne
Mission Manager: Tim Cole

Foreign government or space agency participation: N/A

Summary of NASA's responsibility under the governing agreement(s): N/A

1.1 Schedule of upcoming mission milestones:

- Shipment of spacecraft: Q3 CY2023
- First launch: Q4 CY2023

1.2 Mission Overview:

The Conejo spacecraft is a computing technology demonstration mission in Low-Earth Orbit (LEO). The Mission purpose is to acquire Spaceflight heritage of the computing hardware and fully characterize hardware and software performance in space environments. The spacecraft will be passive and self-contained experiment with the bus only providing power and telemetry and command. The spacecraft bus is based on the Astro Digital Corvus Micro design. This standardized satellite bus uses reaction wheels, magnetic torque coils, star trackers, magnetometers, sun sensors, and gyroscopes to enable precision 3-axis pointing without the use of propellant.

1.3 Launch Vehicles and Launch Sites:

Launching on a SpaceX Falcon 9 rideshare mission, launch site TBD.

1.4 Proposed Initial Launch Date:

Q4 2023

1.5 Mission Duration:

The design lifetime of the spacecraft hardware is a minimum of 3 years. The time to complete the mission is expected to be 1 year.

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

SpaceX Falcon 9 is expected to deliver the spacecraft to a target operational orbit of 525 +/- 25 km and a worst-case orbital altitude of 550 km. The spacecraft will operate for 6 months from an orbit with the following parameters:

- Target Orbital Altitude: 525 km
- Worst Case Orbital Altitude: 550 km
- Eccentricity: 0.0000 to 0.0033
- Inclination: 97.4° to 97.8°

After the spacecraft has demonstrated all relevant technologies and completed payload operations, it will be passivated and allowed to enter an uncontrolled re-entry trajectory.

2 Spacecraft Description

2.1 Physical description of the spacecraft

The Conejo is based on the standard Corvus Micro. The total mass is 48.5 kg. The satellite has dimensions of 103.5 x 38.5 x 63 cm**.** The satellite structure is comprised of six aluminum orthogrid plates, in which all components are mounted on the inner and outer faces. All structural panels are referenced against the body frame of the spacecraft as seen on Figure 1. A base plate on the +X, four side plates two on the +/-Y and two on the +/-Z axis and an upper plate on the -X axis.

A total of three Main Solar Panels (MSPs) are used as the primary source of power generation. These MSPs are body mounted in the + Y axis and each have dimensions of 45 cm x 32 cm x 0.16 cm. Two of the MSPs are stowed for launch and deploy from the +/- Z faces after separation. The deployment mechanism is a spring-loaded hinge with a burn wire that is activated upon separation. Two additional keep alive panels are mounted on the spacecraft, one on the -Y face and the other one on the -X face. They each have dimensions of 22.1 cm x 17.1 cm x 0.16 cm. A total of 3 Coarse Attitude Determination System (CADS) boards are placed on the +/-Y and +X axis. The CADS boards have dimensions of 12.1 cm x 1.3 cm x 0.16 cm, and contain electronics embedded in them such as a coarse sun sensor and magnetometer.

The satellite avionics are enclosed inside the Data Power Module (DPM) which is comprised of a flight computer with integrated IMU, GPS module, TT&C transceiver, two battery packs, charging module, power distribution module and a high voltage power board. An additional battery pack containing two Direct Energy Pack (DEP) is also used to further supply power to the payload, regulate the high loads which the MSPs generate and provide temperature monitor and heaters. All the avionics components have previously flown in different Astro Digital missions. The satellite is equipped with a TT&C transceiver, Turva S-band/UHF. Two UHF antennas are placed on two opposite plates of the +/-X axis. Two S-band patch antennas are placed in the lower corners of the +/-Y axis. One Gen4 Ka-band transceiver is equipped to provide high speed payload data downlink. This transceiver is mounted in the interior of the satellite's X plate with the antenna mounted on the exterior of that same plate. The GPS is mounted inside the DPM and with its corresponding antenna mounted on the -Y axis.

The Attitude Determination and Control System (ADCS) consists of flight proven externally sourced hardware with one star tracker, a gyroscope, reaction wheels and torque rods. In addition to the external hardware a torque rod control module and a reaction wheel control module are used to regulate the high load required by these components. The star tracker is placed on +X panel.

The primary payload components are mounted to the -Y and -Z panel and are comprised of three major subsystems. The Optics board and Electronics board on the -Y panel and the Laser board on the -Z panel. The Optics board is 29cm x 33cm x 13cm, the Electronics board 17cm x 24cm x 11cm and the Laser board 20cm x 23cm x 4cm.

An 11.7-inch Planetary Systems Corporation Lightband on the +X panel of the satellite is used to deploy the spacecraft from the launch vehicle. (37 cm dia x 5.7 cm thickness)

2.2 Detailed illustration of the spacecraft

An illustration of the spacecraft is shown in Figure 1 below:

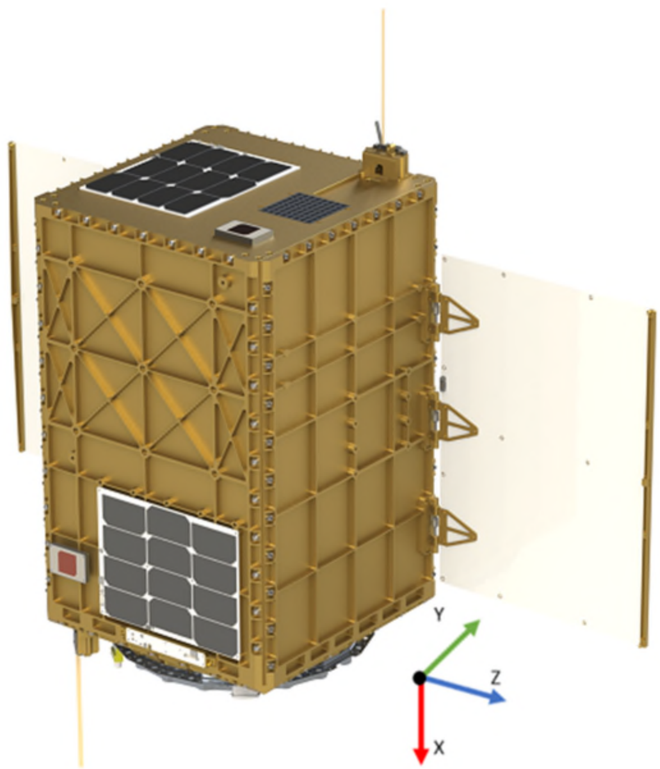

Figure 1: Conejo Spacecraft

2.3 Total Satellite Mass

The current best estimate for total satellite mass is **48.5 kg**

2.4 Dry Mass of the Satellite

48.5 kg

2.5 Identification of All Fluids On-board

N/A

2.6 Description of Propulsion System

N/A. The system does not have propulsion.

2.7 Description of Attitude Control System

Scheduling after separation will consist of autonomous de-tumble followed by a safe mode sun tracking mode. Note that the spacecraft will be launched into a sun-synchronous orbit for which the amount of sunlight it will see throughout an orbit will vary depending on the LTDN. All the following attitude modes use a combination of the following sensors and actuators to perform maneuvers. A magnetometer, sun sensors, gyroscope, reaction wheels, torque rods and star trackers are used to orientate the spacecraft correctly.

ADCS Mode	Description
Nominal	The spacecraft will be tracking the sun vector on its +Y body axis to generate sufficient power to charge the batteries.
TT&C	During TT&C mode the spacecraft can perform a slew to track the ground station but may not be required based on the antenna placement and attitude of the spacecraft.
Downlink	The spacecraft will perform a slew to track the corresponding ground station when line of sight is available. The antenna is located on its -X body axis.

Table 2: Spacecraft ADCS Modes

2.8 Fluids in Pressurized Batteries

None, the Conejo spacecraft uses unpressurized COTS lithium-ion battery cells.

2.9 Description of Pyrotechnic Devices

N/A

2.10 Description of Electrical and Power System

Power is generated by the 3 Main Solar Panels (MSP), with one located on the +Y body face of the spacecraft with the other two deploying from the +/-Z faces to face the +Y. Each MSP is comprised of 14 cells in series with 3 strings for a total of 42 cells per panel. The MSPs peak power generation comes out to be 46 W per panel. Two keep alive panels face the -Y direction and one on the -X serve as backup power generators in case of an uncontrolled tumble or clocking maneuvers. These keep alive panels are comprised of 12 cells in series with a power generation of 13 W per panel.

The Conejo spacecraft will have two battery packs to accommodate the high energy capacity that the payload requires. The DPM battery pack contains a set of 8 Lithium-Ion battery cells in parallel with a capacity of 144 W-hrs. The DEP contains a set of 7 Lithium-Ion battery cells in series, with a capacity of 126 W-hrs. There are a total of two DEPs on Conejo that will be connected in parallel to provide a total battery pack capacity of 252 W-hrs. The battery packs are all equipped with power regulation ICs which regulate the discharge state of the individual battery cells. All the power regulation required for operating the bus is done through the DPM. The DEP batteries function as the primary source of energy storage while the DPM batteries are used as backup. All battery packs are charged through the solar panels.

The satellite bus consumes 15W to 22W of power nominally with certain modes reducing or increasing the load. The payload is expected to consume between 70W depending on which components are being used CBE plus margin. The charge/discharge cycle is managed by a power management system is overseen by the Flight Computer and Electrical Power Subsystem.

2.11 Identification of Other Stored Energy

N/A

2.12 Identification of Any Radioactive Materials

N/A

3 Assessment of Debris Released During Normal Operations

3.1 Identification of Objects Expected to be Released at Any Time

N/A

3.2 Rationale for Release of Objects

N/A

3.3 Time of Release of Objects

N/A

3.4 Release Velocity

N/A

3.5 Expected Orbital Parameters After Object Release

N/A

3.6 Calculated Orbital Lifetime of Release Objects

N/A

3.7 Assessment of Compliance with Requirement 4.3-1 and 4.3-2

3.7.1 Requirements 4.3-1

"All debris released during the deployment, operation, and disposal phases shall be limited to a maximum orbital lifetime of 25 years from date of release. The total object-time product shall be no larger than 100 object-years per mission. For the purpose of this standard, satellites smaller than a 1U standard CubeSat are treated as mission-related debris and thus are bound by this definition to collectively follow the same 100 object-years per mission deployment limit"

Compliance Statement Compliant

3.7.2 Requirements 4.3-2

N/A

4 Assessment of Spacecraft Intentional Breakups and Potential for Explosions

4.1 Identification of all potential causes of spacecraft breakup during deployment and mission operation

Lithium-ion battery cell failure (see 4.2 for further detail)

4.2 Summary of failure modes and effects analyses of all credible failure modes which

may lead to an accidental explosion

The in-orbit 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 such an explosion.

4.3 Detailed plan for any designed spacecraft breakup, including explosions and intentional collisions

None planned.

4.4 List of components which shall be passivated at End of Mission (EOM) including method of passivation and amount which cannot be passivated

After the satellite has reached its End of Lifetime (EOL) its 18 Lithium-Ion Battery Cells (4 DPM & 14 DEP) will be discharged completely. The solar array charging circuit will be disabled, which will fully discharge all cells within a few days.

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

N/A

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

4.6.1 Requirement 4.4-1

"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

1) **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 spacecraft due to the lack of penetration energy to the multiple enclosures surrounding the batteries.
   - Probability: Extremely Low. It is believed to be less than 0.01% given that multiple independent faults must occur for each failure to cause an explosion. Each battery cell is UL/UN certified with individual over-voltage and over-current protection. Identical batteries have been flown on all Astro Digital spacecraft. Even in extreme cases (such as a launch vehicle hydrazine explosion in proximity to the spacecraft), the batteries showed no signs of damage or degradation.

Failure Mode 1: Internal short circuit

- Mitigation: Protoflight level sine burst, sine and random vibration in three axes of both spacecraft, thermal vacuum cycling of both spacecraft and extensive functional testing followed by maximum system rate-limited charge and discharge cycles were performed to prove that no internal short circuit sensitivity exists. Additional environmental and functional testing of the batteries at the power subsystem vendor facilities were also conducted on the batteries at the component level.
- 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: Battery 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, thermal vacuum environment (5 cycles at 50° C, then to -20°C) in order to test the upper limit of the cell's capability. No failures were observed or identified via satellite telemetry or via external monitoring circuitry.
- Combined faults required for realized failure: Spacecraft 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: This failure mode is negated by:
  - Qualification tested short circuit protection on each external circuit,
  - Design of battery packs and insulators such that no contact with nearby board traces is possible without being caused by some other mechanical failure,
  - Observation of such other mechanical failures by protoflight level environmental tests (sine burst, random 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: Battery venting is not inhibited by the battery holder design or the spacecraft design. The battery is capable of venting gases to the external environment.
- Combined faults required for realized failure: The cell manufacturer OR the satellite integrator fails to install proper venting.

Failure Mode 5: Crushing

- Mitigation: Batteries are enclosed within spacecraft structure. Expected relative velocities of spacecraft and docking target are not conducive to structure disassembly. 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: These modes are negated by:
  - Battery holder/case design made of non-conductive plastic, and
  - 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: Thermal rise has been analyzed in combination with space environment temperatures showing that batteries do not exceed normal allowable operating temperatures under a variety of modeled cases, including worst case orbital scenarios. Analysis shows these temperatures to be 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.

1.1.1 Requirement 4.4-2

"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 spacecraft includes the ability to fully disconnect the Lithium Ion cells from the charging current of the solar arrays. Once the satellite reaches its End of Life (EOL), this feature will be used to completely passivate the batteries by removing all energy from them. 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, the debris from the battery rupture should be contained within the spacecraft due to the lack of penetration energy to the multiple enclosures surrounding the batteries.

1.1.2 Requirement 4.4-3

N/A

1.1.3 Requirement 4.4-4

N/A

5.0 Assessment of Potential for On-Orbit Collisions

5.1 Assessment of Compliance with Requirement 4.5-1 and 4.5-2

5.1.1 Requirement 4.5-1

"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 does not

exceed 0.001. For spacecraft and orbital stages passing through the protected region ±200 km and ±15 degrees of geostationary orbit, the probability of accidental collision with space objects larger than 10 cm in diameter shall not exceed 0.001 when integrated over 100 years from time of launch"

Compliance Statement

- Status: Compliant
- Probability: 1.0906E-05

5.1.2 Requirement 4.5-2

"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 maneuver requirements does not exceed 0.01"

Compliance Statement

- Status: Compliant

5.2 Identification of all systems or components required to accomplish any post-mission disposal operation, including passivation and maneuvering

The Flight Computer, Telemetry Transceiver and Electrical Power Subsystem are needed to complete passivation operations. The spacecraft will passively reenter within 9.484 years regardless of any orbit lowering maneuver.

6.0 Assessment of Post-Mission Disposal Plans and Procedure

6.1 Description of Spacecraft Disposal Option Selected

The satellite will de-orbit naturally by atmospheric re-entry.

6.2 Plan for any spacecraft maneuvers required to accomplish post- mission disposal

N/A

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

- Spacecraft Mass: 48.5 Kg
- Cross-sectional Area: 0.5549 m^2 (Random Tumbling)
  - The cross-sectional area for the analysis was calculated for a random tumbling scenario where the spacecraft attitude is variable and has no particular direction.
- Area to mass ratio: 0.01144 m^2/kg

6.4 Assessment of Compliance with Requirement 4.6-1 Through 4.6-4

6.4.1 Requirement 4.6-1

"A spacecraft or orbital stage with a perigee altitude below 2,000 km shall be disposed of by one of the following three methods:"

- 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; or maneuver the space structure into a controlled de-orbit trajectory as soon as practical after completion of mission

- Storage orbit option: Maneuver the space structure into an orbit with perigee altitude above 2000km and ensure its apogee altitude will be below 19,700 km, both for a minimum of 100 years
- Direct retrieval: Retrieve the space structure and remove it from orbit within 10 years after completion of mission

Compliance Statement The orbit lifetime was assessed using the DAS Orbit Evolution Analysis tool. The estimate time of reentry, given the spacecraft parameters depicted in Section 6.3, is to be 9.484 years after station keeping ceases. The estimated time falls under the required orbit dwell time. Figure 2 depicts the Apogee and Perigee of the orbit over time. Station keeping ceases six months from the launch date.

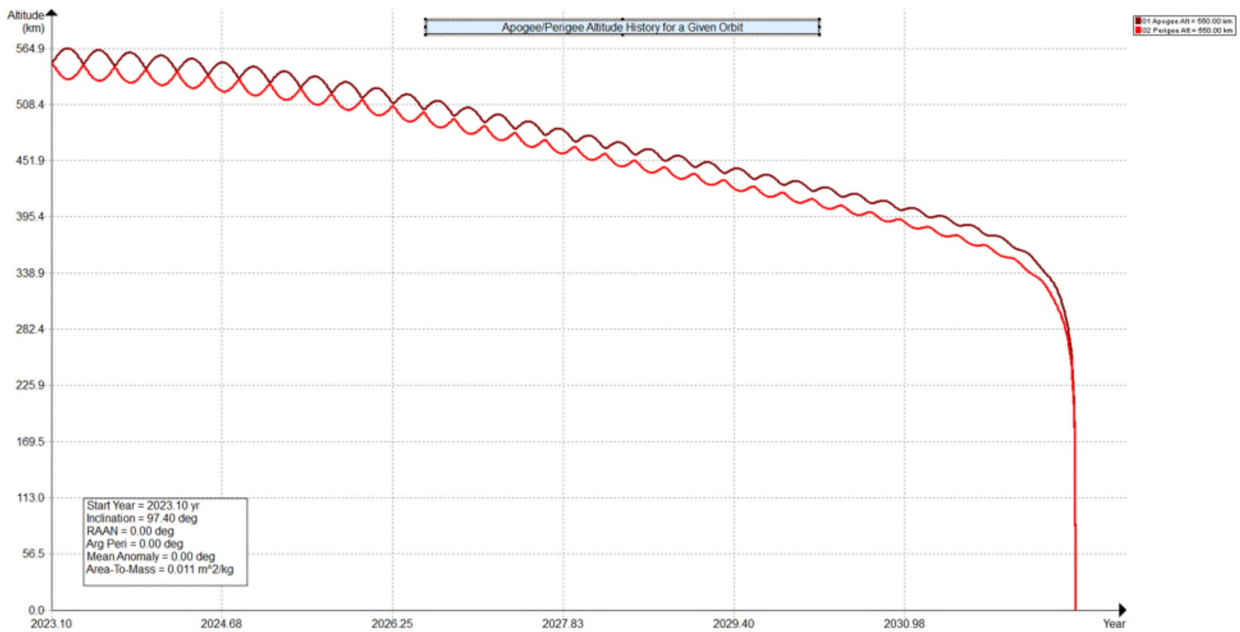

Figure 2: Orbital History

6.4.2 Requirement 4.6-2

N/A

6.4.3 Requirement 4.6-3

N/A

6.4.4 Requirement 4.6-4

The spacecraft will satisfy the requirement of deorbiting within 25 years after deployment as discussed in Section 6.4.1 Reliability of passive deorbit has been validated through different missions in which the accuracy of the orbit’s dwell time has a small variation of a couple of months.

7.0 Assessment of Reentry Hazards

Astro Digital's bus is designed for demise in that all material selections are prioritized to have a low melting point and density, such as aluminum, where materials known to survive re-entry, such as tungsten or titanium, are avoided in large quantities. The spacecraft design is based on Astro Digital heritage designs as submitted and approved in prior ODAR filings.

7.1 Assessment of Compliance with Requirement 4.7-1

7.1.1 Requirement 4.7-1

"The potential for human casualty is assumed for any object with an impacting kinetic energy in excess of 15 joules:"

- For uncontrolled reentry, the risk of human casualty from surviving debris shall not exceed 0.0001(1:10,000)
- 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
- For controlled reentries, the product of the probability of failure to execute the reentry burn and the risk of human casualty assuming uncontrolled reentry shall not exceed 0.0001 (1:10,000)

Compliance Statement DAS calculates that one component, a laser board that is part of the payload, will survive reentry with the risk of human casualty being 1:97400.

Appendix

DAS output :

Processing Requirement 4.3-1: Return Status : Not Run

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

=============== End of Requirement 4.3-1 ===============
Processing Requirement 4.3-2: Return Status : Passed

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

=============== End of Requirement 4.3-2 ===============
Processing Requirement 4.5-1:   Return Status : Passed

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

INPUT

Space Structure Name = P1008
Space Structure Type = Payload
Perigee Altitude = 550.000 (km)
Apogee Altitude = 550.000 (km)
Inclination = 97.400 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0114 (m^2/kg)
Start Year = 2023.100 (yr)
Initial Mass = 48.500 (kg)
Final Mass = 48.500 (kg)
Duration = 5.000 (yr)
Station-Kept = False
Abandoned = True
Long-Term Reentry = False

OUTPUT

Collision Probability = 1.0906E-05

Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

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

=============== End of Requirement 4.5-1 ===============
Requirement 4.5-2: Compliant

=============== End of Requirement 4.5-2 ===============
Processing Requirement 4.6 Return Status : Passed

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

INPUT

Space Structure Name = P1008
Space Structure Type = Payload

Perigee Altitude = 550.000000 (km)
Apogee Altitude = 550.000000 (km)
Inclination = 97.400000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.011440 (m^2/kg)
Start Year = 2023.100000 (yr)
Initial Mass = 48.500000 (kg)
Final Mass = 48.500000 (kg)
Duration = 5.000000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 452.300509 (km)
PMD Apogee Altitude = 476.157953 (km)
PMD Inclination = 97.578636 (deg)
PMD RAAN = 0.242262 (deg)
PMD Argument of Perigee = 78.091157 (deg)
PMD Mean Anomaly = 0.000000 (deg)
Long-Term Reentry = False

OUTPUT

Suggested Perigee Altitude = 452.300509 (km)
Suggested Apogee Altitude = 476.157953 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2032 (yr)
Requirement = 61
Compliance Status = Pass

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

============== End of Requirement 4.6 ===============
*********Processing Requirement 4.7-1 Return Status : Passed

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

name = P1008
quantity = 1
parent = 0
materialID = 8
type = Box
Aero Mass = 48.500000
Thermal Mass = 48.500000
Diameter/Width = 0.630000
Length = 1.030000
Height = 0.390000

name = Structural Panel +X
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 2.640000
Thermal Mass = 2.640000
Diameter/Width = 0.370000
Length = 0.370000
Height = 0.030000

name = Structural Panel -X
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.140000
Thermal Mass = 1.140000
Diameter/Width = 0.350000
Length = 0.350000
Height = 0.020000

name = Structural Panel +Y
quantity = 1
parent = 1

materialID = 8
type = Box
Aero Mass = 1.650000
Thermal Mass = 1.650000
Diameter/Width = 0.350000
Length = 0.560000
Height = 0.010000

name = Structural Panel -Y
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.820000
Thermal Mass = 1.820000
Diameter/Width = 0.350000
Length = 0.560000
Height = 0.010000

name = Structural Panel +Z
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.720000
Thermal Mass = 1.720000
Diameter/Width = 0.350000
Length = 0.560000
Height = 0.010000

name = Structural Panel -Z
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.720000
Thermal Mass = 1.720000
Diameter/Width = 0.350000
Length = 0.560000
Height = 0.010000

name = Corner Rails
quantity = 4
parent = 1
materialID = 8
type = Box
Aero Mass = 0.210000
Thermal Mass = 0.210000

Diameter/Width = 0.032000
Length = 0.470000
Height = 0.032000

name = Star tracker bracket
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.050000
Length = 0.070000
Height = 0.050000

name = Star tracker
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.110000
Thermal Mass = 0.110000
Diameter/Width = 0.090000
Length = 0.110000
Height = 0.090000

name = Reaction wheel bracket
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.700000
Thermal Mass = 0.700000
Diameter/Width = 0.120000
Length = 0.134000
Height = 0.108000

name = DPM
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 2.860000
Thermal Mass = 2.860000
Diameter/Width = 0.152000
Length = 0.240000
Height = 0.090000

name = DEP
quantity = 2
parent = 1
materialID = 8
type = Box
Aero Mass = 1.220000
Thermal Mass = 1.220000
Diameter/Width = 0.190000
Length = 0.420000
Height = 0.120000

name = XCOMM
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 2.000000
Thermal Mass = 2.000000
Diameter/Width = 0.120000
Length = 0.120000
Height = 0.110000

name = HPA
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.210000
Thermal Mass = 0.210000
Diameter/Width = 0.050000
Length = 0.070000
Height = 0.030000

name = XPU
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.730000
Thermal Mass = 0.730000
Diameter/Width = 0.100000
Length = 0.120000
Height = 0.090000

name = Reaction wheel
quantity = 3
parent = 1
materialID = 8

type = Box
Aero Mass = 0.230000
Thermal Mass = 0.230000
Diameter/Width = 0.070000
Length = 0.080000
Height = 0.040000

name = Torque board
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.030000
Length = 0.090000
Height = 0.010000

name = Torque Rod
quantity = 3
parent = 1
materialID = 19
type = Box
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.030000
Length = 0.050000
Height = 0.020000

name = Gyro
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.080000
Thermal Mass = 0.080000
Diameter/Width = 0.040000
Length = 0.050000
Height = 0.020000

name = Solar Panel Hinge
quantity = 6
parent = 1
materialID = 8
type = Box
Aero Mass = 0.040000
Thermal Mass = 0.040000
Diameter/Width = 0.070000

Length = 0.080000
Height = 0.010000

name = Keep alive panel
quantity = 3
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.370000
Thermal Mass = 0.370000
Diameter/Width = 0.170000
Length = 0.220000

name = Main solar panel (deployed)
quantity = 2
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 1.310000
Thermal Mass = 1.310000
Diameter/Width = 0.320000
Length = 0.450000

name = Main solar panel (body mounted)
quantity = 1
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.780000
Thermal Mass = 0.780000
Diameter/Width = 0.320000
Length = 0.450000

name = Smart panel
quantity = 2
parent = 1
materialID = 23
type = Box
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.020000
Length = 0.150000
Height = 0.010000

name = Ka antena
quantity = 1
parent = 1
materialID = 8

type = Box
Aero Mass = 0.240000
Thermal Mass = 0.240000
Diameter/Width = 0.080000
Length = 0.080000
Height = 0.020000

name = S-band RX antenna
quantity = 3
parent = 1
materialID = 8
type = Box
Aero Mass = 0.040000
Thermal Mass = 0.040000
Diameter/Width = 0.040000
Length = 0.060000
Height = 0.010000

name = GPS antenna
quantity = 2
parent = 1
materialID = 8
type = Box
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.030000
Length = 0.030000
Height = 0.020000

name = UHF antenna
quantity = 2
parent = 1
materialID = 8
type = Box
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.030000
Length = 0.050000
Height = 0.010000

name = Optics board
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 6.120000
Thermal Mass = 6.120000
Diameter/Width = 0.290000

Length = 0.330000
Height = 0.130000

name = Electronic board
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 5.970000
Thermal Mass = 5.970000
Diameter/Width = 0.170000
Length = 0.240000
Height = 0.110000

name = Laser board
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 4.910000
Thermal Mass = 4.910000
Diameter/Width = 0.200000
Length = 0.230000
Height = 0.040000

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

name = P1008
Demise Altitude = 77.992798
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel +X
Demise Altitude = 63.786125
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel -X
Demise Altitude = 71.584511
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel +Y
Demise Altitude = 71.835297

Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel -Y
Demise Altitude = 71.187309
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel +Z
Demise Altitude = 71.570030
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel -Z
Demise Altitude = 71.570030
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Corner Rails
Demise Altitude = 76.402466
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Star tracker bracket
Demise Altitude = 76.597534
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Star tracker
Demise Altitude = 76.621422
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Reaction wheel bracket
Demise Altitude = 71.859222
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = DPM
Demise Altitude = 63.715050

Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = DEP
Demise Altitude = 74.087791
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = XCOMM
Demise Altitude = 61.755329
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = HPA
Demise Altitude = 71.297241
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = XPU
Demise Altitude = 70.421959
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Reaction wheel
Demise Altitude = 72.448288
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Torque board
Demise Altitude = 76.374519
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Torque Rod
Demise Altitude = 73.368210
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Gyro
Demise Altitude = 73.365150

Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Solar Panel Hinge
Demise Altitude = 76.453018
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Keep alive panel
Demise Altitude = 75.303467
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Main solar panel (deployed)
Demise Altitude = 73.878708
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Main solar panel (body mounted)
Demise Altitude = 75.447647
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Smart panel
Demise Altitude = 77.092178
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Ka antena
Demise Altitude = 70.978691
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = S-band RX antenna
Demise Altitude = 75.452377
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = GPS antenna
Demise Altitude = 74.801758

Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = UHF antenna
Demise Altitude = 75.396805
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Optics board
Demise Altitude = 56.150841
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Electronic board
Demise Altitude = 53.481289
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Laser board
Demise Altitude = 0.000000
Debris Casualty Area = 0.586959
Impact Kinetic Energy = 8901.131836

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