Orbital Debris Assessment Report (ODAR)

DAS Software v3.2.6

This report is presented as in compliance with NASA-STD-8719.14C, Appendix A and 47 C.F.R. § 5.64.

October 22, 2024

APPROVAL:

Name	Position	Company
Jack Ackohen	Program Manager	Astro Digital

Revision History

Revision	Date	Author(s)	Description
1.0	12/19/2023	CA	Initial Release
1.1	02/06/2024	CA	Updated launch mission to Transporter-11
1.2	10/22/2024	CA	Updated launch mission to Transporter-13. Re-ran analysis using newest DAS version (3.2.6) and newest Solar Flux table (06/27/2024)
1.3	1/17/2025		Updated to reflect mission duration, de-orbit, and propulsion clarifications.

Table of Contents

List of Tables

List of Figures

Self-Assessment per NASA-STD-8719.14C

A self-assessment in accordance with the format provided in Appendix A.2 of NASA-STD-8719.14C is shown below in **Error! Reference source not found.**.

Section	Status	Comment
4.3-1: Planned debris release passing through LEO	Compliant	
4.3-2: Planned debris release passing near GEO	N/A	Not passing through GEO
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 breakups for Earth and lunar missions	Compliant	
4.4-4: Limiting the short-term risk to other space systems from planned breakups for Earth orbital missions	Compliant	
4.5-1: Limiting debris generated by collisions with large objects when in Earth orbit	Compliant	
4.5-2: Limiting debris generated by collisions with small objects when operating in Earth orbit	Compliant	
4.6-1: Natural reentry, direct reentry, or direct retrieval	Compliant	
4.6-2: Storage and Earth escape	N/A	Not passing through GEO
4.6-3: Long-term reentry for space structures in Medium Earth Orbit (MEO), Tundra orbits, highly inclined GEO, and other orbits	N/A	Not moving in between orbits
4.6-4: Reliability of post mission disposal maneuver operations in Earth orbit	Compliant	
4.7-1: Limit the risk of human casualty	Compliant	
4.8-1, Special classes of space missions	N/A	Standard mission

Table 1:Assessment Report Format

Assessment Report Format

This ODAR follows the format in NASA-STD-8719.14C, 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:
Carlos Aizcorbe
Astro Digital Director of Program Management:
Jack Ackohen

Foreign government or space agency participation: **None**
Summary of NASA's responsibility under the governing agreement(s): **N/A**

1.1 Schedule of upcoming mission milestones:

- Shipment of spacecraft: Q1 CY2025
- First launch: Q1 CY2025

1.2 Mission Overview:

The Cortez spacecraft[1] is a technology demonstration mission. The spacecraft is designed and manufactured by Astro Digital and is based on the Corvus Micro platform. This standardized satellite bus uses 3 reaction wheels, 3 magnetic torque coils, 1 star tracker, 4 magnetometers, 4 sun sensors and 2 IMU to provide precision 3-Axis control without requiring the use of propellant for station keeping or attitude control.

1.3 Launch Vehicles and Launch Sites:

SpaceX Falcon 9 rideshare mission Transporter-13, launch site Vandenberg, California.

1.4 Proposed Initial Launch Date:

Q1 2025

1.5 Mission Duration:

The design lifetime of the spacecraft hardware is a minimum of 5 years. The time to complete the mission is discussed in the narrative attachment.

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

The selected launch vehicle will deliver the Cortez Spacecraft directly to its operational circular sun-synchronous orbit at an altitude of 510 km +/-15km of uncertainty provided by the launch service. The spacecraft will operate for 24 months from an orbit with the following parameters:

- Average Orbital Altitude: 510km +/-15km[2]
- Eccentricity: 0.0000 to 0.004 (TBC)

[1] The Cortez spacecraft is also known as the MITRE Space Experimentation Lab or M-SEL.
[2] The orbit of the Cortez spacecraft will naturally decay over its on-orbit lifetime as illustrated in Section 6.4.1, Figure 2 below. The spacecraft's propulsion system will not be used for orbital maintenance. *See* 47 C.F.R. § 5.64(b)(4)(i)(D).

- Inclination: Sun-Synchronous Orbit +/- 0.1 deg (TBC)

2 Spacecraft Description

2.1 Physical description of the spacecraft

The Cortez spacecraft is based on the standard Corvus-Micro+ bus.The total wet mass is 39.81 (CBE) and total dry mas is 38.51 (CBE). The satellite has dimensions of 37x111x57cm. 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 main structural panel in the +Y axis, two side plates on the +Z axis, a base plate on the –X and +X and a payload deck on the -Z axis.

Three Mian Solar Panels (MSPs) are used as the primary power generation source. 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 from the Falcon 9 upper stage. The deployment mechanism is a spring-loaded hinge with a burn wire that is activated upon separation. Three additional keep alive panels are mounted on the spacecraft, one on the -Y face and the other two on the +/- Z faces. They each have dimensions of 22.1 cm x 17.1 cm x 0.16 cm. A total of 4 Smart Panels (SP) are placed on the -Y and +/-Z axis. The Smart Sensor Panels 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 the top corners of the spacecraft –Y and +Y panels. A Total of 4 S-band patch antennas are mounted as follow: Two S-band patch antennas are placed in the lower corners of the –Y panel, one in the +Y panel and the last one in the –X panel. The GPS module is mounted inside the DPM and its corresponding antenna is mounted on the +Y axis.

The Attitude Determination and Control System (ADCS) consists of flight proven externally sourced hardware with one star tracker, 2 IMU sensors, 3 reaction wheels and 3 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 propulsion subsystem is based on the Enpulsion Micro R3. The thruster is located on the external +X face with the thruster nozzles pointed outward align with the X axis. The subsystem separates into two modules, the thruster head (140mm x 120mm x 98.6mm) which includes 1.3Kg of propellant mass and the Power Processing Unit (PPU) (140mm x 120mm x 34).

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. (10.04 dia x 2.1 thickness)

The payload subsystem is fixed to the –Y panel and is composed by the following components, the Payload and Radio Integrated Module (PRIM), the Receive Frequency Multiplexer (RxFMUX), the Transmit Frequency Multiplexer (TxFMUX), the C-band Filter Amplifier (CFA), The X-band High Power Amplifier (XHPA) and X-band Up Converter (XUPCONV) mounted internally to the panel and the Wideband Antenna (WBA), also known as the FUSE antenna, covering L-, S-, and C-bands, and X-band and C-band mounted externally to the panel.

The Cortez satellite will utilize active tracking by communicating through approved ground stations and utilizing onboard GPS receivers to maintain accurate positional data. Prior to deployment, the satellite will be registered with the 18th Space Control Squadron (18th SCS). Throughout the mission, the satellite operator will actively share information regarding initial deployment, ephemeris data, and any planned maneuvers with the 18th SCS to support space situational awareness and effective traffic management with other operational space stations in the same orbit and any inhabitable spacecraft throughout the orbital lifetime of the space station.[3]

Upon receipt of a space situational awareness conjunction warning, the satellite operator will review and take all possible steps to assess the collision risk, and will mitigate the collision risk if necessary. As appropriate, steps to assess and mitigate the collision risk should include, but are not limited to: contacting the operator of any active spacecraft involved in such a warning; sharing ephemeris data and other appropriate operational information with any such operator; and modifying space station attitude and/or operations.[4]

2.2 Detailed illustration of the spacecraft

An illustration of the spacecraft is shown below:

[3] *See id.* § 5.64(b)(4)(i)(B),(C), (b)(5).

[4] *See id.* § 5.64(b)(4)(i)(E).

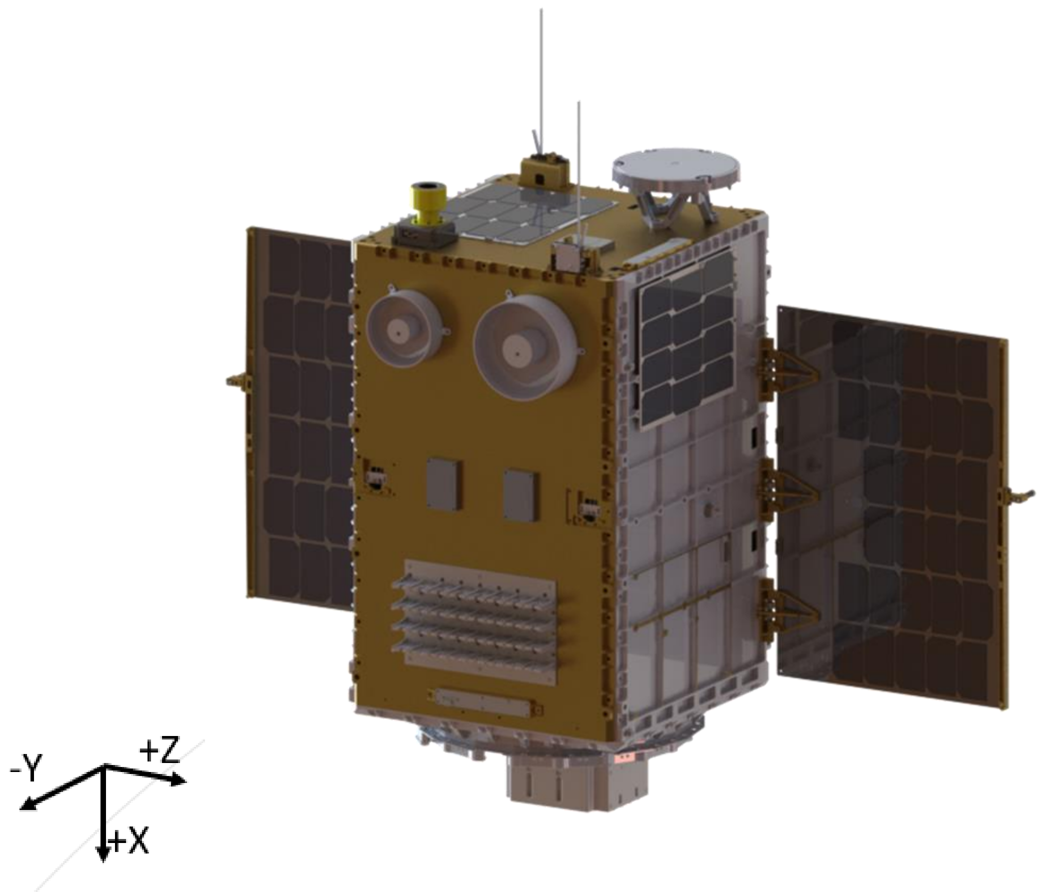

Figure 1: Cortez Spacecraft

2.3 Total Satellite Mass

Current best estimate (CBE) of 39.81kg and up to 42.24kg with 6.1% margin.

2.4 Dry Mass of the Satellite

Considering 1.3Kg of propellant mass the CBE dry mass of the satellite is 38.51kg and 40.94kg with 6.1% margin.

2.5 Identification of All Fluids On-board

The Enpulsion Micro R3 propulsion system includes 1.3Kg of non-toxic indium as propellant.

2.6 Description of Propulsion System

The Enpulsion Micro R3 propulsion system uses Field Emission Electric Propulsion technology that consists of an emitter and an accelerator electrode that generated electric potential difference of several kV accelerating the indium particles from the emission tips. The indium propellant is a non-combustible, non-explosive compound and relies on an electromagnetic field to accelerate ionized particles for propulsion. No part of the Enpulsion Micro R3 propulsion system is pressurized and no chemical energy is stored. The Cortez spacecraft bus platform for this mission was repurposed from a previous mission. The MITRE mission inherited its propulsion system from a prior program with a different mission profile, which required propulsion maneuvers. At this stage, modifications to the propulsion system were no longer feasible, so the decision was made to fly the spacecraft as is, including the propulsion system, despite it having no operational requirements or goals. However, the ODAR document requires a detailed description of the spacecraft and all its subsystems. As a result, a description of the propulsion unit was included for completeness. The Cortez spacecraft will not use the propulsion unit at any time during the mission, not for station keeping nor de-orbiting. The spacecraft will de-orbit due to drag within the required timeframe as discussed in Section 6 below.

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 up 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.
Payload Operations	During nominal payload operations the spacecraft will slew to track ground station with the -Y axis and slew back to sun track mode tracking the sun with +Y vector to recharge batteries.
Decommissioning	The spacecraft will be tracking velocity vector with the +X axis and clocking with the +Y vector the sun while firing the thruster.

Table 2: Spacecraft ADCS Modes

2.8 Fluids in Pressurized Batteries

None, Cortez spacecraft uses unpressurized standard lithium-ion battery cells. The DPM battery pack contains two sets of 4 Lithium-Ion battery cells in parallel with a total capacity of 160 W-hrs and 2 sets of additional energy packages called Direct Energy Package with 7 cells in series with a total capacity of 280 W-hrs, giving a total of 440W-hrs of battery capacity.

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. Three keep alive panels face the -Y direction and one on the +Z 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.

Cortez bus will have two additional battery packs to accommodate the high load that the payload requires called Direct Energy Package (DEP). The DPM battery pack contains a set of 8 Lithium-Ion battery cells in parallel with a capacity of 160 W-hrs. The DEP contains a set of 7 Lithium-Ion battery cells in series, with a capacity of 140W-hrs. DEPs are connected in parallel to provide a total battery pack capacity of 280W-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 though 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 18W of power nominally with certain modes reducing or increasing the load. The payload is expected to consume between 15 to 105W depending on which components are being used., CBE plus margin.

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 spacecraft. 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

There is no planned or intentional release for debris by the Spacecraft.[5] The demise report complies with both scenarios in which the spacecraft can demise within 5-years after its mission has ended and subsequently satisfying the 25-year requirement.[6] Additional information is presented in Section 6.4I

3.7.2 Requirements 4.3-2

N/A

[5] *See id.* § 5.64(b)(1).

[6] *See id.* § 5.64(b)(7)(iv).

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

N/A

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.[7]

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

N/A

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 22 Lithium-Ion Battery cells 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[8]

- Required Probability: 0.001
- Expected Probability:0.000

Supporting Rationale and FMEA Details

- Battery Explosion
  - Effect: All failure modes below might result in battery explosion with the possibility of orbital debris generation. However, in the unlikely event that a battery cell does explosively rupture, the small size, mass, and potential energy, of these small batteries is such that while the spacecraft could be expected to vent gases, most debris from the battery rupture should be contained within the spacecraft due to the lack of

[7] *See id.* § 5.64(b)(3).

[8] *See id.* § 5.64(b)(4)(i)(A)

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: Proto-flight 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) 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 proto-flight 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 space-craft design. The battery can vent 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: This mode is negated by spacecraft design. There are no moving parts in the proximity of the batteries.
- Combined faults required for realized failure: A catastrophic failure must occur in an external system AND the failure must cause a collision sufficient to crush the batteries leading to an internal short circuit AND the satellite must be in a naturally sustained orbit at the time the crushing occurs.

- Failure Mode 6: Low level current leakage or short-circuit through battery pack case or due to moisture-based degradation of insulators.
  - Mitigation: 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: The spacecraft thermal design will negate this possibility. Thermal rise has been analyzed in combination with space environment temperatures showing that batteries do not exceed normal allowable operating temperatures 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.

4.6.2 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.

4.6.3 Requirement 4.4-3

N/A

4.6.4 Requirement 4.4-4

N/A

5 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, the program or project shall demonstrate that, during the orbital lifetime of each spacecraft and orbital stage, the probability of accidental collision with space objects larger than 10 cm in diameter is less than 0.001. For the purpose of this assessment, 100 years is used as the maximum orbital lifetime for the storage disposal option.”

Compliance Statement:
Status: Compliant
Probability: 1.4694E-6

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[9]

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, Electrical Power Subsystem.

[9] *See id.* § 5.64(b)(2).

6 Assessment of Post-Mission Disposal Plans and Procedure

6.1 Description of Spacecraft Disposal Option Selected

The spacecraft will de-orbit and re-enter due to atmospheric drag. The values used for this analysis are representative of a nominal scenario in which the spacecraft can deploy its solar panel after launch. Unless extended or subsequent experimental testing is authorized for the Cortez spacecraft, MITRE will promptly commence deorbit activities following the conclusion of experimental testing and there would not be a 40-month delay to begin this process. It will take around 9 months to fully de-orbit the Cortez once MITRE commences the deorbit process.

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

Spacecraft will de-orbit due to atmospheric drag after 4.668yr after launch. Therefore, no additional maneuvers are required to accomplish passively re-enter within 5 years.

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

- Spacecraft Mass: 39.8 Kg (CBE)
    - Current best estimate plus margin is used to assess reentry criteria giving a lower area to mass ratio which in turn increases the orbit dwell time.
- Cross-sectional Area: 0.42839 m2
    - The cross-sectional area for the analysis was calculated for a random tumbling scenario where the spacecraft attitude is variable and has no direction.
- Area to mass ratio: 0.01076m2/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

<u>**Compliance Statement:**</u> Compliant**,** the orbit lifetime was assessed using the DAS Orbit Evolution

Analysis tool. The estimated time of reentry, given the spacecraft parameters depicted in Section 6.3, and a worst-case altitude of 525km is to be 4.668years. Figure 2 depicts the Apogee and Perigee of the orbit over time for the worst-case altitude drop off and the post-maneuver.

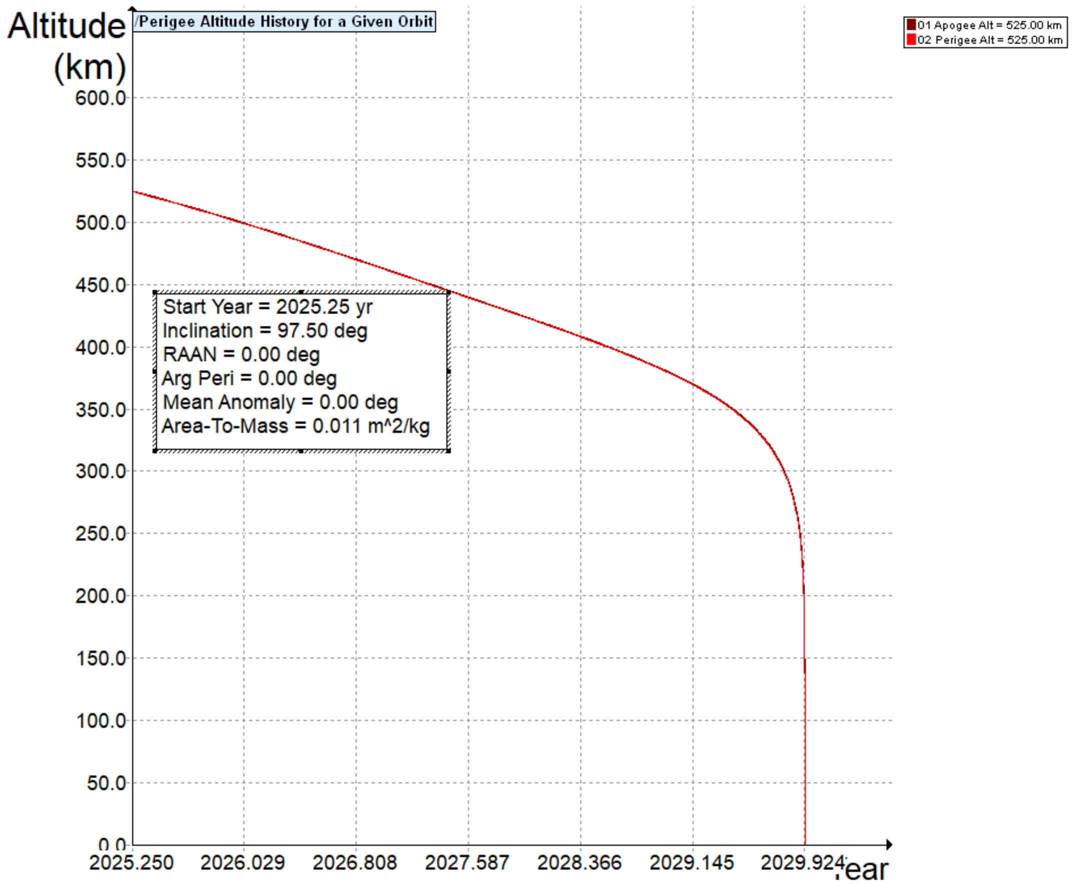

Figure 2: Nominal Orbital History DAS3.2.6 using Solar Flux table up to date 06/27/2024

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 5 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 Assessment of Spacecraft 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. The Cortez spacecraft design is based on Astro Digital heritage designs as submitted and approved in prior ODAR filings. This spacecraft does not incorporate any new development materials.

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 the risk of human casualty for uncontrolled re-entry at 0 which meets the limit the risk of human casualty requirement of not exceeding 0.0001 (1:10,000).[10] All components are listed in detail in the full DAS results and show they will demise upon reentry in appendix A.

[10] *Id.* § 5.64(b)(7)(ii), (iii), (iv)(B).

8 Assessment of Special Classes of Space Missions

N/A

Appendix A: DAS Output Log

10 22 2024; 16:27:50PM Activity Log Started
10 22 2024; 16:34:41PM Science and Engineering - Orbit Lifetime/Dwell Time

INPUT

Start Year = 2025.250000 (yr)
Perigee Altitude = 525.000000 (km)
Apogee Altitude = 525.000000 (km)
Inclination = 97.500000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.010760 (m^2/kg)

OUTPUT

Orbital Lifetime from Startyr = 4.668131 (yr)
Time Spent in LEO during Lifetime = 4.668131 (yr)
Last year of Propagation = 2029 (yr)
Returned Error Message: Object reentered
10 22 2024; 16:35:37PM Science and Engineering - Apogee/Perigee History for a Given Orbit

INPUT

Perigee Altitude = 525.000000 (km)
Apogee Altitude = 525.000000 (km)
Inclination = 97.500000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.010760 (m^2/kg)
Start Year = 2025.250000 (yr)
Integration Time = 5.000000 (yr)

OUTPUT

Plot

=============== End of Requirement 4.3-1 ===============
10 22 2024; 16:16:11PM Processing Requirement 4.3-2: Return Status : Passed

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

=============== End of Requirement 4.3-2 ===============
10 22 2024; 16:19:21PM Processing Requirement 4.5-1: Return Status : Passed

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

INPUT

Space Structure Name = Cortez
Space Structure Type = Payload
Perigee Altitude = 525.000 (km)
Apogee Altitude = 525.000 (km)
Inclination = 97.500 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0108 (m^2/kg)
Start Year = 2025.250 (yr)
Initial Mass = 39.800 (kg)
Final Mass = 39.800 (kg)
Duration = 5.000 (yr)
Station-Kept = False
Abandoned = True
Long-Term Reentry = False

OUTPUT

Collision Probability = 3.0483E-06
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

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

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

10 22 2024; 16:19:25PM Project Data Saved To File
10 22 2024; 16:19:46PM Requirement 4.5-2: Compliant

=============== End of Requirement 4.5-2 ===============

10 22 2024; 16:19:49PM Processing Requirement 4.6 Return Status : Passed

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

INPUT

Space Structure Name = Cortez
Space Structure Type = Payload

Perigee Altitude = 525.000000 (km)
Apogee Altitude = 525.000000 (km)

Inclination = 97.500000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.010760 (m^2/kg)
Start Year = 2025.250000 (yr)
Initial Mass = 39.800000 (kg)
Final Mass = 39.800000 (kg)
Duration = 5.000000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = -1.000000 (km)
PMD Apogee Altitude = -1.000000 (km)
PMD Inclination = 0.000000 (deg)
PMD RAAN = 0.000000 (deg)
PMD Argument of Perigee = 0.000000 (deg)
PMD Mean Anomaly = 0.000000 (deg)
Long-Term Reentry = False

OUTPUT

Suggested Perigee Altitude = 525.000000 (km)
Suggested Apogee Altitude = 525.000000 (km)
Returned Error Message = Reentry during mission (no PMD req.).

Released Year = 2029 (yr)
Requirement = 61
Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
10 22 2024; 16:24:03PM *********Processing Requirement 4.7-1
Return Status : Passed

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

name = Cortez
quantity = 1
parent = 0
materialID = 8
type = Box
Aero Mass = 39.799999
Thermal Mass = 39.799999
Diameter/Width = 0.400000
Length = 0.825000
Height = 0.400000

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

materialID = 8
type = Box
Aero Mass = 2.680000
Thermal Mass = 2.680000
Diameter/Width = 0.370000
Length = 0.370000
Height = 0.030000

name = Structural Panel -X
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.370000
Thermal Mass = 1.370000
Diameter/Width = 0.350000
Length = 0.350000
Height = 0.020000

name = Structural Panel +Y
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.800000
Thermal Mass = 1.800000
Diameter/Width = 0.350000
Length = 0.520000
Height = 0.010000

name = Structural Panel -Y
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.700000
Thermal Mass = 1.700000
Diameter/Width = 0.350000
Length = 0.490000
Height = 0.010000

name = Structural Panel +Z
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.610000
Thermal Mass = 1.610000
Diameter/Width = 0.350000
Length = 0.490000
Height = 0.010000

name = Structural Panel -Z
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.550000
Thermal Mass = 1.550000
Diameter/Width = 0.350000
Length = 0.490000
Height = 0.010000

name = Corner Rails
quantity = 4
parent = 1
materialID = 8
type = Box
Aero Mass = 0.180000
Thermal Mass = 0.180000
Diameter/Width = 0.032000
Length = 0.470000
Height = 0.032000

name = Star tracker bracket
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.230000
Thermal Mass = 0.230000
Diameter/Width = 0.070000
Length = 0.100000
Height = 0.055000

name = Star tracker
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.230000
Thermal Mass = 0.230000
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 = 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 = 0.048600
Thermal Mass = 0.048600
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 = 3
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 = PRIM
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 = X antenna
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.150000
Thermal Mass = 0.150000
Diameter/Width = 0.080000
Length = 0.300000

name = C antenna
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.150000
Thermal Mass = 0.150000
Diameter/Width = 0.080000
Length = 0.300000

name = wideband antenna
quantity = 1
parent = 1
materialID = 8

type = Box
Aero Mass = 1.360000
Thermal Mass = 1.360000
Diameter/Width = 0.100000
Length = 0.200000
Height = 0.100000

name = S-band RX antenna
quantity = 4
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 = 1
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 = TxFMUX
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.010000

name = RxFMUX

quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.010000

name = CFA
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.010000

name = CLNA
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.040000
Thermal Mass = 0.040000
Diameter/Width = 0.050000
Length = 0.050000
Height = 0.010000

name = HPA
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.090000
Thermal Mass = 0.090000
Diameter/Width = 0.050000
Length = 0.070000
Height = 0.030000

name = Payload Computer
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.500000
Thermal Mass = 1.500000
Diameter/Width = 0.210000
Length = 0.290000

Height = 0.066000

name = Enpulsion Micro - Thruster head
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 2.600000
Thermal Mass = 2.600000
Diameter/Width = 0.120000
Length = 0.140000
Height = 0.100000

name = Enpulsion PPU
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.300000
Thermal Mass = 1.300000
Diameter/Width = 0.140000
Length = 0.340000
Height = 0.120000

name = Harness
quantity = 33
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.300000
Length = 0.200000

name = Fasteners
quantity = 40
parent = 1
materialID = 8
type = Box
Aero Mass = 0.010000
Thermal Mass = 0.010000
Diameter/Width = 0.250000
Length = 0.250000
Height = 0.250000

name = Astroscale Docking Plate
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.400000
Thermal Mass = 0.400000

Diameter/Width = 0.150000
Length = 0.150000

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

name = Cortez
Demise Altitude = 77.999552
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel +X
Demise Altitude = 76.267502
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel -X
Demise Altitude = 77.002639
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel +Y
Demise Altitude = 77.082593
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel -Y
Demise Altitude = 77.082576
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel +Z
Demise Altitude = 77.126097
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel -Z
Demise Altitude = 77.162146
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Corner Rails
Demise Altitude = 77.740007
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Star tracker bracket
Demise Altitude = 77.247736
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Star tracker
Demise Altitude = 77.492481
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Reaction wheel bracket
Demise Altitude = 76.884339
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = DPM
Demise Altitude = 75.247183
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = DEP
Demise Altitude = 77.350802
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Reaction wheel
Demise Altitude = 76.942167
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Torque board
Demise Altitude = 77.698208
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Torque Rod
Demise Altitude = 76.806864
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Gyro
Demise Altitude = 77.087926

Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Solar Panel Hinge
Demise Altitude = 77.726925
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Keep alive panel
Demise Altitude = 76.277856
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Main solar panel (deployed)
Demise Altitude = 75.688177
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Main solar panel (body mounted)
Demise Altitude = 76.623472
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Smart panel
Demise Altitude = 77.384193
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = PRIM
Demise Altitude = 74.692198
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = X antenna
Demise Altitude = 77.643296
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C antenna
Demise Altitude = 77.643296
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = wideband antenna
Demise Altitude = 76.352693
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = S-band RX antenna
Demise Altitude = 77.520899
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = GPS antenna
Demise Altitude = 77.384827
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = UHF antenna
Demise Altitude = 77.506389
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = TxFMUX
Demise Altitude = 77.860460
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = RxFMUX
Demise Altitude = 77.860460
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = CFA
Demise Altitude = 77.536360
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = CLNA
Demise Altitude = 77.492712
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = HPA
Demise Altitude = 77.406179
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Payload Computer
Demise Altitude = 76.717696
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Enpulsion Micro - Thruster head
Demise Altitude = 74.099583
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Enpulsion PPU
Demise Altitude = 77.110779
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Harness
Demise Altitude = 77.954162
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Fasteners
Demise Altitude = 77.999552
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Astroscale Docking Plate
Demise Altitude = 76.894575
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

============== End of Requirement 4.7-1 ==============
10 22 2024; 16:24:03PM Project Data Saved To File