<u>EXHIBIT B</u>

LAUNCHER INC. ORBITAL DEBRIS ASSESSMENT REPORT FOR ORBITER SN3 SPACECRAFT

Orbiter SN3
Orbital Debris Assessment Report (ODAR)

Revision 1.0

Debris Assessment Software (DAS) version used in analysis: v3.2.3

Document data is not restricted.

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

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1. Program Management and Mission Overview

Launcher is a U.S. company headquartered in Hawthorne, California.

1.1 Program Manager

- Max Haot

1.2 Foreign Government or Space Agency Participation

- None

1.3 Mission Milestone Schedule

Milestone	Date
Vehicle Delivery	May 2023
Vehicle Launch and Deployment	June 2023

1.4 Mission Overview

Orbiter SN3 is expected to launch in June 2023 into a circular sun-synchronous, low-Earth orbit (LEO). The expected insertion and operational orbit is 525 ± 25 km at an inclination of 97.5 +/- 0.1 deg. This orbit is selected due to availability of regular launches on SpaceX Transporter missions. Operational lifetime is expected to be less than 2 years. Once deployed from the launch vehicle, Orbiter SN3 will ultimately release 4 customer spacecraft payloads while 3 customer non-radiofrequency payloads and 1 non-deploying mass simulator remain.[1] The four deploying payloads will be housed in cubesat deployers

[1] This non-deploying mass simulator is being flown instead of de-manifested customer spacecraft.

prior to deployment.[2] The OtterPup spacecraft will separate from Orbiter SN3 via a 11.7-inch Planetary Systems Corporation Lightband. The OtterPup primary mission will be to approach and re-dock with Orbiter SN3. Orbiter SN3 will coordinate approach and docking maneuvers with Starfish Space. For additional information on the rendezvous and proximity operations, please see ELS File No. 1117-EX-CN-2022.

At the end of its mission, Orbiter SN3 will passivate by venting all onboard gas and rely on drag for atmospheric reentry and disposal.

1.5 Launch

Orbiter SN3 will launch on board a SpaceX Falcon 9 rocket as part of the Transporter-8 mission in June 2023 from Vandenberg Space Force Base, California.

1.6 Mission Duration

The anticipated operational lifetime of Orbiter SN3 is less than 2 years. The on-orbit lifetime is approximately 13.3 years in LEO (Low Earth Orbit).

2. Spacecraft Description

2.1 Physical description of the spacecraft

The vehicle is composed of five primary structures: separation ring, propulsion tank array, a central truss structure, and the top plate. Other significant structures include a Smart CSD cubesat dispenser, the Otter Pup payload, three fixed body-mounted solar panels, and other payloads identified in the attached legal narrative.

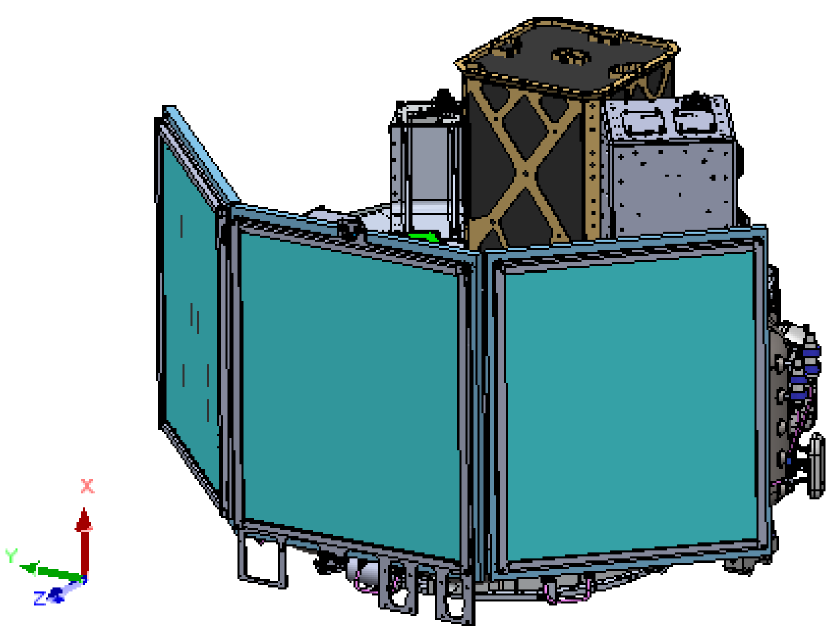
Avionics components include six S-band antennas, two S-band transceivers, an in-house flight computer, and a Battery Management System (BMS) consisting of two lithium ion

[2] See Legal Narrative for additional information on the payloads.

batteries containing a total of 450 Wh capacity with an integrated battery charging circuit using current from the solar panels. Additional avionics components include the Integrated Power Box (IPB), which controls load switching of avionics, and Payload Distribution Box (PDB), which provides power to satellite deployers and hosted payloads and contains a secondary battery, pressure transducers, and thermocouples. Both the BMS and PDB batteries are controlled by an inhibit circuit in the BMS, which remains off when Orbiter is mounted to the launch vehicle. Ground communications are achieved with the transceivers and six patch antennas.

An in-house separation system, the LSS24, will be used to deploy Orbiter from the launch vehicle, from which no debris will be generated. Separation is accomplished using a non-pyrotechnic and field reset-able release mechanism from EBAD with proven flight heritage.

Orbiter SN3 will carry cameras to image the spacecraft and its payloads.



Orbiter SN3 Overview

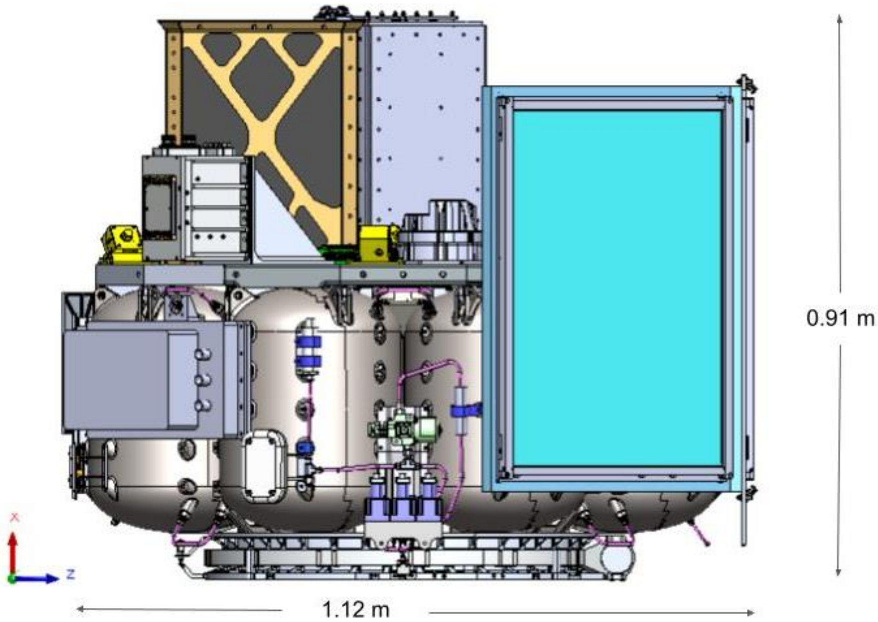
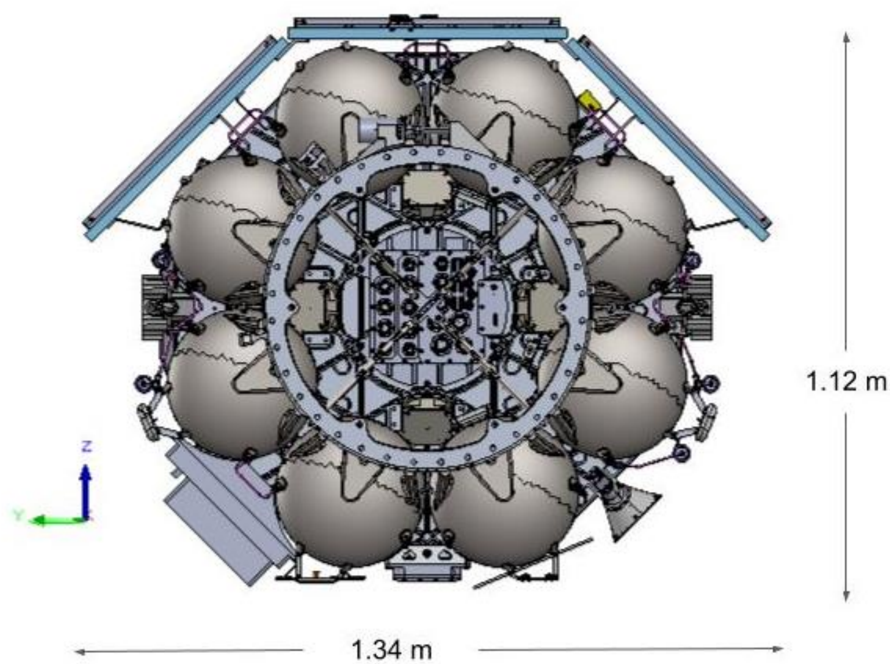


Figure: Orbiter SN3 X-Z Plane



Orbiter SN3 Y-Z Plane

2.2 Spacecraft Mass

- Flyaway Wet Mass prior to payload deployments: 223.2 kg

- Wet Mass after all payload deployed: 188 kg
- Dry Mass after all payloads deployed: 186 kg

2.3 Description of propulsion system

Orbiter SN3 utilizes its two 3-axis cold gas thruster clusters for reaction wheel desaturations or in the case that more than one reaction wheel fail. These thrusters can also provide a small amount of delta-V, which will be used to perform collision avoidance maneuvers with other spacecraft or debris. The thruster system uses unregulated argon gas as the propellant. The gas is stored in 8 tanks with a volume of 23 L each. A total of 2 kg of argon gas is pressurized to 90 psig prior to launch.

2.4 Description of Attitude Control System

The Guidance, Navigation, and Control (GNC) system consists of two star trackers, two sun sensors, two inertial measurement units (IMUs) (each containing 3 accelerometers and 3 gyroscopes), four reaction wheels, two 3-axis cold gas thruster clusters, and one Global Positioning System (GPS) receiver, including two GPS antennas.

The GNC subsystem has several operational modes that enable the spacecraft to execute its mission:

- A *detumbling mode* is used to reduce angular rates below a threshold after launch vehicle separation or system reboot. Rotation rate measurements from the IMUs are employed to null out vehicle rates using thrusters and reaction wheels.
- A *standby mode* is used to maximize solar power generation while also allowing communications with the ground network using omnidirectional antennas. Standby mode is entered during vehicle commissioning (after a software reboot) or autonomously by the flight software when it detects a low battery state of charge or other critical vehicle fault. During this mode, the spacecraft will maintain its solar panels pointing towards the sun using either sun sensor or solar panel

illumination measurements. If the sun cannot be found using these sensors, the spacecraft will begin a lighthouse maneuver and roll until it requires the sun.

- A *pointing mode* is used to slew and orient the spacecraft in either inertial or relative coordinate frames using Star Trackers and IMUs. This mode is used for payload deployments, proximity operations, tracking of ground targets, or pointing in inertial space.
- A *ground station mode* is used to slew to and track ground stations, which is required for high data rate communications. Low rate telemetry, tracking, and command (TT&C) communications does not require dedicated ACS due to the use of omnidirectional antennas
- An *axial thruster firing mode* is used for collision avoidance and other small delta-V maneuvers.
- A *vehicle safing mode* is used to vent the remaining propellant in the vehicle's tanks and prepare the vehicle for decommissioning and atmospheric re-entry.

During nominal operations, the four reaction wheels provide redundant 3-axis attitude control and thrusters are used for reaction wheel desaturations. The nominal vehicle attitude is sun pointing (with the +Z axis of the vehicle aligned with the sun vector) when in view of the sun and performing the lighthouse roll maneuver when in eclipse.

2.5 Description of any range safety or other pyrotechnic devices

None.

2.6 Description of the electrical generation and storage system

Power is generated using the three body-mounted solar panels located on the +Z half of the spacecraft, with maximum power achieved when the spacecraft's +Z body vector is aligned with the sun pointing vector. The total peak power generation of the solar panels is 140 W.

The primary energy storage is provided by two COTS Lithium-Ion 225 Wh battery packs connected in parallel with each pack containing two cells wired in series. This yields a total energy capacity of 450 Wh.

The secondary battery housed in the PDB is a COTS Lithium-Ion battery comprised of two 18650 cells in series. This battery has a capacity of 24 Wh. Both the BMS and PDB batteries receive power from the solar panels and are charged before payload integration. An additional non-rechargeable COTS Lithium-Ion coin cell battery is housed in the IPB for use as an RTC (real-time-clock). This battery has a capacity of 0.15 Wh.

The vehicle nominally consumes approximately 64 W of instantaneous power but may draw more (if in pass or with active payloads) or less (if in standby) depending on the mode of operation. Power draw can range from 44 to 156 W. The solar panels collect approximately 115 Wh of solar energy per orbit. The charge/discharge cycle is managed by the BMS which is monitored by the flight computer.

The deployable payloads described above contain their own electrical generation and storage systems.

2.7 Identification of any other sources of stored energy not noted above

Reaction wheels store kinetic energy but can be disconnected from power at the end of the operational lifetime. If power is lost, the wheels will dissipate their energy into the vehicle and it will build up a low rotation rate.

2.8 Identification of any radioactive material on board

None.

2.9 Description of planned proximity operations or docking

Orbiter plans to perform proximity operations and docking with the Otter Pup payload.[3] The Otter Pup vehicle will be deployed from Orbiter and perform a sequence of proximity operations and ultimately attempt to dock with Orbiter. Orbiter will hold an attitude to support Otter Pup's proximity operations and docking activities. Orbiter will not perform any slew operations during this period. Once docking is successfully completed, the Otter Pup vehicle will release itself from Orbiter and perform its own extended mission operations and vehicle disposal.

3. Assessment of Debris Released During Normal Operations

3.1 Identification of objects expected to be released

There are no intentional releases beyond the 4 customer spacecraft deployments. See attached recontact analysis.

3.2 Rationale/necessity for release of each object

N/A

3.3 Time of release of objects relative to launch time

N/A

3.4 Release velocity of each object

N/A

3.5 Expected orbital parameters of each object

N/A

[3] *See* Starfish Space, Orbital Debris Assessment Report, ELS File No. 1117-EX-CN-2022 (filed Jan. 3. 2023). *See generally* ELS File No. 1117-EX-CN-2022.

3.6 Calculated orbital lifetime of each object

N/A

3.7 Assessment of Spacecraft Compliance with Requirements 4.3-1 and 4.3-2

3.7.1 Requirement 4.3-1: Mission Related Debris Passing Through LEO

Requirement 4.3-1: Planned debris release passing through LEO – released debris with diameters of 1mm or larger:

a. Requirement 4.3-1a: 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.

b. Requirement 4.3-1b: The total object-time product shall be less than 100 object-years per launch vehicle upper stage or per spacecraft.

Compliance statement: Compliant. No release of debris will occur during the lifetime of Orbiter SN3.

3.7.2 Requirement 4.3-2: Mission Related Debris Passing Near GEO

Requirement 4.3-2: Planned debris release passing near GEO: For missions leaving debris in orbits with the potential of traversing GEO (GEO altitude +/- 200 km and +/- 15 degrees inclination), released debris with diameters of 5 mm or greater shall be left in orbits which will ensure that within 25 years after release the apogee will no longer exceed GEO - 200 km or the perigee will not be lower than GEO + 200 km , and also ensures that the debris is incapable of being perturbed to lie within that GEO +/- 200 km and +/- 15 zone for at least 100 years thereafter.

Compliance statement: Compliant. This requirement is not applicable to this mission profile.

4. Spacecraft Intentional Breakups and Potential for Explosions

4.1 Potential causes of spacecraft breakup during deployment and mission operations

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

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

The spacecraft has no chemically reactive propellants nor is it a hazardous pressure system. The battery safety systems are discussed in the assessment of spacecraft compliance with ODAR requirement 4.4-1, which describes the combined faults required for the mutually exclusive failures that lead to battery venting. The batteries are COTS batteries equipped with safety vent features that release excessive pressure build-up, precluding explosions.

4.3 Plan for any designed spacecraft breakup

There are no planned breakups.

4.4 List of components which shall be passivated at EOM

- **Propulsion System** – residual inert propellant will be expended by venting via thrusters.
- **Reaction Wheels** – reaction wheels will be commanded to 0 rpm.

4.5 Rationale for Non-Passivation

Not applicable.

4.6 Assessment of Spacecraft Compliance with Requirements 4.4-1 through 4.4-4

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

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

Pressure Vessel Explosion:

- **Effect:** A rupture of one propellant tank would release inert argon gas. The leak would induce a tumble on the spacecraft, but no additional debris would be generated.
- **Probability:** Extremely low, estimated to be 0.001%.
- **Mitigation:** Tanks are expected to leak before bursting. Additionally, the tank design burst pressure is 600 psig. Tanks will be pressurized to 90 psig prior to launch. Thermal environments are not expected to increase tank pressure to the design burst pressure. Telemetry from the previous spacecraft (Orbiter SN1), which was pressurized to the same level, showed internal tank pressure at 46 psig upon first contact with the spacecraft.

Battery Explosion:

- **Effect:** All failure modes below might result in battery explosion. However, in the unlikely event that a battery cell does explosively rupture, the small size, mass, and potential energy of individual cells, coupled with enclosures surrounding the batteries packs, will ensure debris from the battery rupture should be contained within the spacecraft due to the lack of penetration energy. Gasses may be vented through non-hermetic battery enclosures.

- **Probability:** Extremely low, estimated to be 0.001% given that multiple independent (not common mode) faults must occur for each failure mode to cause the ultimate effect (explosion).
- **Failure Mode 1:** Internal cell short circuit
  - **Mitigation:** The two primary (225 Wh each) battery packs are designed, manufactured, and tested in accordance with MIL-PRF-32052/1, which requires that a cell overcharge, short circuit, or forced discharge shall not result in an explosion. In addition, if venting occurs to mitigate pressure build-up, the battery case shall prevent dimensional expansion. These battery packs are also in compliance with UN 38.3 specifications.

    The small size, mass, and potential energy of secondary battery pack and RTC cells are such that debris from the cell rupture would be contained within the vessel due to the lack of penetration energy. The effect of such an event is further minimized by compliance of the cells to UL-1642 or UN 38.3 specifications.
  - **Combined faults required for realized failure:** Environmental testing **<u>AND</u>** 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 UL/UN tested in lab for high load discharge rates by short circuiting the terminal to determine the feasibility of an out-of-control thermal rise in the cell.
  - **Combined faults required for realized failure:** Spacecraft thermal design must be incorrect **<u>AND</u>** 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; and
        - Obviation of such other mechanical failures by proto-qualification and acceptance environmental tests (shock, vibration, thermal cycling, and thermal-vacuum tests).
    - **Combined faults required for realized failure:** An external load must fail/short-circuit **AND** external over-current detection **AND** disconnect function must all occur to enable this failure mode.
- **Failure Mode 4:** Inoperable vents
    - **Mitigation:** Battery venting is not inhibited by the battery holder design or the spacecraft design. The battery can vent gasses to the external environment.
    - **Combined faults required for realized failure:** The cell manufacturer and the satellite integrator must fail to install proper venting.
- **Failure Mode 5:** Crushing
    - **Mitigation:** Failure mode prevented by design. No moving parts appear near the battery assembly. All batteries are in aluminum enclosures. Battery cells are UL/UN tested for crush and impact.
    - **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 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 for this failure mode.
- **Failure Mode 7:** Excess battery cell temperature 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 the 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. Battery cells are UL/UN thermal tested without fire or explosion.
    - **Combined faults required for realized failure:** Incorrect thermal analysis **AND** thermal design **AND** mission simulations in thermal-vacuum chamber testing **AND** over-current monitoring and control must all fail for this failure mode to occur.

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

- *Design of all spacecraft and launch vehicle orbital stages shall include the ability to deplete all onboard sources of stored energy and disconnect all energy generation sources when they are no longer required for mission operations or 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:** All remaining propellant will be vented through the thruster system at EOM. The reaction wheels will be commanded to 0 rpm. Without active control, the vehicle will tumble and lose power.

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.

5. Assessment of Potential for On-Orbit Collisions

In addition to the below requirements being met, it should be noted that Orbiter SN3's propulsion system will allow Launcher to react to potential collision events and avoid collisions.

5.1 Assessment of Spacecraft Compliance with Requirements 4.5-1 and 4.5-2

5.1.1 Requirement 4.5-1: Limiting debris generated by collisions with large objects when operating in Earth orbit

For each spacecraft and launch vehicle orbital stage in or passing through LEO, the program or project shall demonstrate that, during the orbital lifetime of each spacecraft and orbital stage, the probability of accidental collision with space objects larger than 10 cm in diameter is less than 0.001 (Requirement 56506).

Compliance statement: Compliant. See section 6.2 for area-to-mass calculations.

For a nominal mission where all payloads are deployed, area-to-mass ratio of 0.081 m^2/kg, large object impact and debris generation probability is 4.4056E-05.

For a DOA scenario in which no payloads are deployed, area to mass ratio of 0.0068 m^2/kg, large object impact and debris generation probability is 4.8708E-05.

DAS output for nominal scenario.

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Run Data

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INPUT

Space Structure Name = Orbiter SN3

Space Structure Type = Payload

Perigee Altitude = 550.000 (km)

Apogee Altitude = 550.000 (km)

Inclination = 97.493 (deg)

RAAN = 0.000 (deg)

Argument of Perigee = 0.000 (deg)

Mean Anomaly = 0.000 (deg)

Final Area-To-Mass Ratio = 0.0081 (m^2/kg)

Start Year = 2023.500 (yr)

Initial Mass = 186.000 (kg)

Final Mass = 186.000 (kg)

Duration = 2.000 (yr)

Station-Kept = False

Abandoned = True

Long-Term Reentry = False

OUTPUT

Collision Probability = 4.4056E-05

Returned Message: Normal Processing

Date Range Message: Normal Date Range

Status = Pass

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

DAS output for DOA scenario.

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

Run Data

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INPUT

Space Structure Name = Orbiter SN3

Space Structure Type = Payload

Perigee Altitude = 550.000 (km)

Apogee Altitude = 550.000 (km)

Inclination = 97.493 (deg)

RAAN = 0.000 (deg)

Argument of Perigee = 0.000 (deg)

Mean Anomaly = 0.000 (deg)

Final Area-To-Mass Ratio = 0.0068 (m^2/kg)

Start Year = 2023.500 (yr)

Initial Mass = 223.200 (kg)

Final Mass = 223.200 (kg)

Duration = 2.000 (yr)

Station-Kept = False

Abandoned = True

Long-Term Reentry = False

OUTPUT

Collision Probability = 4.8708E-05

Returned Message: Normal Processing

Date Range Message: Normal Date Range

Status = Pass

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

5.1.2 Requirement 4.5-2: Limiting the probability of damage from 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).

Compliance Statement: Compliant. Orbiter SN3 will naturally deorbit via atmospheric reentry.

Identification of all systems or components required to accomplish any post-mission disposal operation, including passivation and maneuvering: No systems are required for reentry.

The following vehicle components will be used to reduce stored energy in the vehicle.

- Flight Computer
- Battery Management System (BMS)
- Integrated Power Box (IPB)

5.2 Operator Procedure for Active Conjunction Avoidance

Launcher is partnering with Slingshot Aerospace to monitor conjunction data messages (CDMs) from the 18th Space Control Squadron. Launcher will initiate collision-avoidance planning if a conjunction prediction falls into the Emergency Criteria specified in the Spaceflight Safety Handbook for Satellite Operators: overall miss ≤ 1km and probability of collision ≥ 1e-04. The target for risk reduction will be as follows: overall miss ≥ 1km and probability of collision ≤ 1e-07.

Launcher's conjunction warning response timeline is as follows:
TCA - 120 hrs: Launcher receives CDM warning.
TCA - 112 hrs: Launcher contacts other satellite operator to assess risk.
TCA - 72 hrs: Launcher assesses risk based on refined prediction. If conjunction falls into emergency criteria, Launcher develops a mitigation plan in coordination with other satellite operator.
TCA - 48 to 24 hrs: Launcher initiates conjunction avoidance maneuver if necessary.

6. Spacecraft Post-mission Disposal Plans and Procedures

6.1 Description of Spacecraft Disposal Option selected

Orbiter SN3 will be disposed of via atmospheric reentry.

At EOM, Orbiter SN3 will vent all remaining argon gas from the propellant tanks and command reaction wheels to 0 rpm. Gas will be vented evenly from all 6 thrusters, which will result in a small imparted delta velocity. The maximum expected delta-V will be 3.82 m/s along the vehicle +X body axis, which corresponds to an orbit change of +/- 15km, assuming a starting operational orbit of 525x525km. This delta-V value is conservative because it assumes the Orbiter SN3 center of gravity lies directly on the vehicle +X body axis. Any lateral CG offset, which is likely, will cause Orbiter SN3 to tumble, further reducing the impact on the orbit.

6.2 Calculation of area-to-mass ratio

Per section 2.1, the cross sectional areas of the Orbiter SN3 XZ, A_{XZ} , and YZ A_{YZ} planes are roughly:

A_{XZ} = 1.12m x 0.91m = 1.019 m^2

A_{YZ} = 1.34m x 1.12m = 1.508 m^2

For the area-to-mass ratio, the XZ plane cross sectional area was used because it results in more conservative orbital lifetime calculation.

If Orbiter SN3 deploys all payloads, this would result in a nominal scenario with the following area-to-mass ratio: 1.019 m^2/ 186 kg = 0.0055 m^2/kg.

If Orbiter SN3 fails to deploy any payloads, this would result in a DOA scenario with the following area-to-mass ratio: 1.019 m^2/ 223.2 kg = 0.0046 m^2/kg.

For the purposes of collision probability in section 5.1.1 (for Requirement 4.5-1), the YZ plane cross sectional area was used because it is the largest envelope, regardless of whether payloads are deployed or not, and therefore results in a more conservative collision probability calculation.

Nominal area-to-mass ratio: 1.508 m^2/ 178 kg = 0.0085 m^2/kg

DOA area-to-mass ratio: 1.508 m^2/ 223.2 kg = 0.0068 m^2/kg

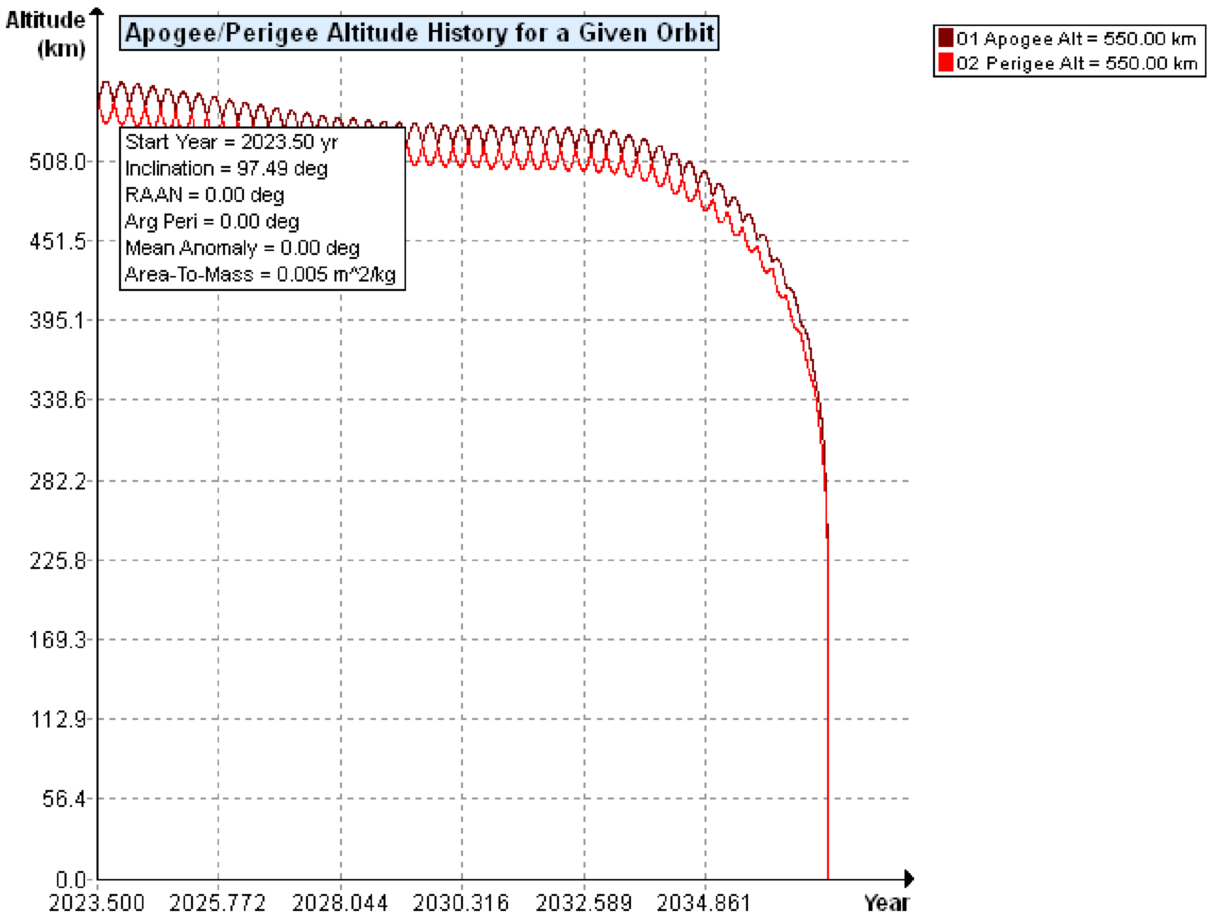
6.3 Assessment of Spacecraft Compliance with ODAR Requirements 4.6-1 to 4.6-4

Requirement 4.6-1(a): Disposal for space structures in or passing through LEO

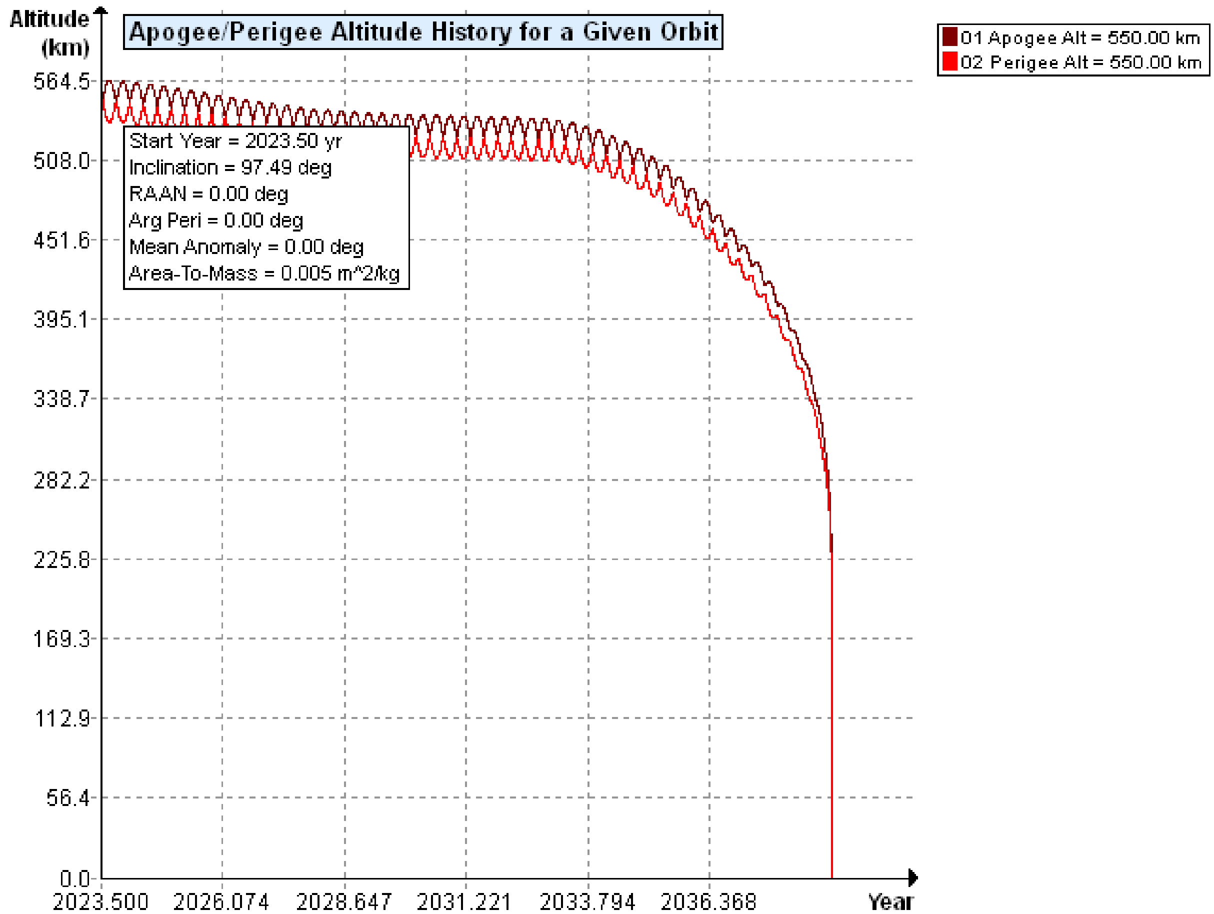
Natural reentry: Leave the space structure in an orbit in which, using conservative projections for solar activity, atmospheric drag will limit the orbital lifetime to as short as practicable but no more than 25 years after the completion of mission.

Compliance statement: Compliant. DAS predicts the orbital lifetime of Orbiter SN3 to be less than 20 years.

Orbiter SN3 lifetime if all payloads are deployed is roughly 13.3 years using the highest possible 550 km altitude.



Orbiter SN3 lifetime if no payloads are deployed is roughly 15.5 years using the highest possible 550 km altitude.



Requirement 4.6-2: Disposal for space structure near GEO

- **Compliance statement:** Not applicable

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

- **Compliance statement:** Not applicable

Requirement 4.6-4: Reliability of post-mission disposal operations

- **Compliance statement:** An EOM maneuver is not required to ensure deorbit within 25 years.

7. Spacecraft Reentry Hazards

Assessment of Spacecraft Compliance with ODAR 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.

Requirement 4.7-1(a): *For uncontrolled reentry, the risk of human casualty from surviving debris shall not exceed 0.0001 (1:10,000) (Requirement 56626).*

Compliance statement: For Orbiter SN3, the calculated risk of human casualty using DAS is 1:38,000. All customer payloads are expected to satisfy this threshold. Additionally, Aerospace Corp has been contracted to perform an independent reentry casualty risk assessment (which might not be complete before licensing is necessary).

Requirement 4.7-1(b): *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 NASA-STD-8719.14C 50 of 77 landmasses, or is within 50 km from the continental U.S., territories of the U.S., and the permanent ice pack of Antarctica*

Compliance statement: Not applicable because controlled reentry is not planned.

Requirement 4.7-1(c): *For controlled reentry, the product of the probability of failure to execute the reentry burn and the risk of human casualty assuming uncontrolled reentry shall be less than 0.0001 (1:10,000).*

Compliance statement: Not applicable because controlled reentry is not planned.

Requirement 4.7-1(c): *For long-term reentry of space structures in MEO, Tundra orbits, highly inclined GEO, and other orbits: Surviving debris shall have less than 7 m2 total debris casualty area or 0.0001 (1 in 10,000) risk of human casualty.*

Compliance statement: Not applicable.

Analysis using DAS v3.2.3

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Project Data

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INPUT

Space Structure Name = Orbiter SN3

Space Structure Type = Payload

Perigee Altitude = 550.000000 (km)

Apogee Altitude = 550.000000 (km)

Inclination = 97.493000 (deg)

RAAN = 0.000000 (deg)

Argument of Perigee = 0.000000 (deg)

Mean Anomaly = 0.000000 (deg)

Area-To-Mass Ratio = 0.008100 (m^2/kg)

Start Year = 2023.500000 (yr)

Initial Mass = 186.000000 (kg)

Final Mass = 186.000000 (kg)

Duration = 2.000000 (yr)

Station Kept = False

Abandoned = True

PMD Perigee Altitude = 530.730947 (km)

PMD Apogee Altitude = 537.507871 (km)

PMD Inclination = 97.534409 (deg)

PMD RAAN = 352.213912 (deg)

PMD Argument of Perigee = 19.932143 (deg)

PMD Mean Anomaly = 0.000000 (deg)

Long-Term Reentry = False

OUTPUT

Suggested Perigee Altitude = 530.730947 (km)

Suggested Apogee Altitude = 537.507871 (km)

Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2035 (yr)

Requirement = 61

Compliance Status = Pass

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=============== End of Requirement 4.6 ===============

02 28 2023; 14:48:36PM *********Processing Requirement 4.7-1

Return Status : Passed

***********INPUT****

Item Number = 1

name = Orbiter SN3

quantity = 1

parent = 0

materialID = 80

type = Cylinder

Aero Mass = 186.000000

Thermal Mass = 186.000000

Diameter/Width = 1.000000

Length = 0.953000

name = Top plate

quantity = 1

parent = 1

materialID = 9

type = Flat Plate

Aero Mass = 18.600000

Thermal Mass = 18.600000

Diameter/Width = 1.000000

Length = 1.000000

name = Propulsion structure

quantity = 1

parent = 1

materialID = 9

type = Cylinder

Aero Mass = 5.000000

Thermal Mass = 5.000000

Diameter/Width = 0.250000

Length = 0.250000

name = Top plate supports

quantity = 4

parent = 1

materialID = 65

type = Cylinder

Aero Mass = 0.360000

Thermal Mass = 0.360000

Diameter/Width = 0.012000

Length = 0.893000

name = Separation ring

quantity = 1

parent = 1

materialID = 9

type = Cylinder

Aero Mass = 3.500000

Thermal Mass = 3.500000

Diameter/Width = 0.090000

Length = 0.365000

name = Control Boxes

quantity = 4

parent = 1

materialID = 8

type = Box

Aero Mass = 2.163000

Thermal Mass = 2.163000

Diameter/Width = 0.133000

Length = 0.285000

Height = 0.025000

name = Sensors

quantity = 32

parent = 1

materialID = 8

type = Box

Aero Mass = 0.246700

Thermal Mass = 0.246700

Diameter/Width = 0.075000

Length = 0.100000

Height = 0.040000

name = Lenses

quantity = 3

parent = 1

materialID = -1

type = Flat Plate

Aero Mass = 0.020300

Thermal Mass = 0.020300

Diameter/Width = 0.100000

Length = 0.100000

name = Secondary Structures

quantity = 50

parent = 1

materialID = 5

type = Flat Plate

Aero Mass = 0.238400

Thermal Mass = 0.238400

Diameter/Width = 0.100000

Length = 0.300000

name = Antennas

quantity = 8

parent = 1

materialID = -2

type = Flat Plate

Aero Mass = 0.150000

Thermal Mass = 0.150000

Diameter/Width = 0.080000

Length = 0.100000

name = Radios and Combiners

quantity = 8

parent = 1

materialID = 5

type = Box

Aero Mass = 0.114500

Thermal Mass = 0.114500

Diameter/Width = 0.065000

Length = 0.083000

Height = 0.017000

name = Batteries

quantity = 1

parent = 1

materialID = -3

type = Box

Aero Mass = 7.100000

Thermal Mass = 7.100000

Diameter/Width = 0.150000

Length = 0.310000

Height = 0.100000

name = Solar Panel Aluminum Frame

quantity = 3

parent = 1

materialID = 5

type = Flat Plate

Aero Mass = 0.900000

Thermal Mass = 0.900000

Diameter/Width = 0.515000

Length = 0.550000

name = Solar Panel Glass Laminate

quantity = 3

parent = 1

materialID = -1

type = Flat Plate

Aero Mass = 0.600000

Thermal Mass = 0.600000

Diameter/Width = 0.500000

Length = 0.530000

name = Solar Panel Cells

quantity = 3

parent = 1

materialID = 23

type = Flat Plate

Aero Mass = 1.200000

Thermal Mass = 1.200000

Diameter/Width = 0.400000

Length = 0.400000

name = Aluminum Honeycomb Plate

quantity = 3

parent = 1

materialID = 5

type = Flat Plate

Aero Mass = 0.600000

Thermal Mass = 0.600000

Diameter/Width = 0.515000

Length = 0.550000

name = Composite Face Sheet

quantity = 6

parent = 1

materialID = 23

type = Flat Plate

Aero Mass = 0.600000

Thermal Mass = 0.600000

Diameter/Width = 0.515000

Length = 0.550000

name = HT025 Composite Spacer

quantity = 3

parent = 1

materialID = 16

type = Flat Plate

Aero Mass = 1.000000

Thermal Mass = 1.000000

Diameter/Width = 0.200000

Length = 0.300000

name = Ti Tanks

quantity = 8

parent = 1

materialID = 65

type = Cylinder

Aero Mass = 5.900000

Thermal Mass = 5.900000

Diameter/Width = 0.063400

Length = 0.403000

name = Plumbing

quantity = 20

parent = 1

materialID = 58

type = Cylinder

Aero Mass = 0.020000

Thermal Mass = 0.020000

Diameter/Width = 0.012700

Length = 5.000000

name = SS Fittings

quantity = 29

parent = 1

materialID = 59

type = Box

Aero Mass = 0.070000

Thermal Mass = 0.070000

Diameter/Width = 0.040000

Length = 0.060000

Height = 0.020000

name = Ti Fittings

quantity = 38

parent = 1

materialID = 65

type = Cylinder

Aero Mass = 0.010000

Thermal Mass = 0.010000

Diameter/Width = 0.014000

Length = 0.031000

name = Valves and Pluming

quantity = 15

parent = 1

materialID = 59

type = Cylinder

Aero Mass = 0.371000

Thermal Mass = 0.371000

Diameter/Width = 0.140000

Length = 0.051000

name = Hosted Payload

quantity = 1

parent = 1

materialID = 5

type = Box

Aero Mass = 13.000000

Thermal Mass = 13.000000

Diameter/Width = 0.240000

Length = 0.380000

Height = 0.240000

name = Hosted Payload 2

quantity = 1

parent = 1

materialID = 5

type = Box

Aero Mass = 4.000000

Thermal Mass = 4.000000

Diameter/Width = 0.120000

Length = 0.150000

Height = 0.110000

name = Cubesat Dispensers

quantity = 1

parent = 1

materialID = 9

type = Box

Aero Mass = 21.130000

Thermal Mass = 13.000000

Diameter/Width = 0.262000

Length = 0.420000

Height = 0.262000

name = 3U Mass Sim

quantity = 1

parent = 26

materialID = 5

type = Box

Aero Mass = 8.130000

Thermal Mass = 8.130000

Diameter/Width = 0.100000

Length = 0.300000

Height = 0.100000

name = TRL Camera

quantity = 4

parent = 1

materialID = 5

type = Box

Aero Mass = 0.063000

Thermal Mass = 0.063000

Diameter/Width = 0.035000

Length = 0.035000

Height = 0.029000

**************OUTPUT****

Item Number = 1

name = Orbiter SN3

Demise Altitude = 77.998333

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Top plate

Demise Altitude = 70.013112

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Propulsion structure

Demise Altitude = 71.359252

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Top plate supports

Demise Altitude = 74.345675

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Separation ring

Demise Altitude = 69.846752

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Control Boxes

Demise Altitude = 75.729336

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Sensors

Demise Altitude = 77.266421

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Lenses

Demise Altitude = 77.904389

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Secondary Structures

Demise Altitude = 76.999762

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Antennas

Demise Altitude = 75.725183

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Radios and Combiners

Demise Altitude = 76.541228

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Batteries

Demise Altitude = 72.429808

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Solar Panel Aluminum Frame

Demise Altitude = 77.138952

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Solar Panel Glass Laminate

Demise Altitude = 77.765783

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Solar Panel Cells

Demise Altitude = 76.257473

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Aluminum Honeycomb Plate

Demise Altitude = 77.430363

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Composite Face Sheet

Demise Altitude = 77.413741

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = HT025 Composite Spacer

Demise Altitude = 0.000000

Debris Casualty Area = 2.033777

Impact Kinetic Energy = 149.621462

****

name = Ti Tanks

Demise Altitude = 54.049655

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Plumbing

Demise Altitude = 77.981607

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = SS Fittings

Demise Altitude = 76.450891

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Ti Fittings

Demise Altitude = 75.748004

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Valves and Pluming

Demise Altitude = 74.873603

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Hosted Payload

Demise Altitude = 68.505793

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Hosted Payload 2

Demise Altitude = 67.835729

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Cubesat Dispensers

Demise Altitude = 70.750799

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = 3U Mass Sim

Demise Altitude = 57.592119

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = TRL Camera

Demise Altitude = 76.179503

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

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

8. Special Classes of Space Missions

8.1 Assessment of Spacecraft Compliance with Requirement 4.8-1

8.1.1 Requirement 4.8-1 Special classes of space missions

Special classes of space missions, including large constellations; rendezvous, proximity operations, and satellite servicing; safety of active debris removal operations; tethers; and small satellites, shall comply with (1) the requirements in Sections 4.3 through 4.7, (2) the applicable mitigation standard practices established in Objective 5 of the 2019 ODMSP, and (3) the following: a. Tether systems: Intact and remnants of severed tether systems in Earth orbit shall limit the generation of orbital debris from on-orbit collisions with other operational spacecraft. Tether systems should generally not remain deployed after the completion of their mission objectives. After mission objectives are met, such tethers should have provisions for disposal (full retraction/stowing and/or removal from Earth orbit) with a probability NASA-STD-8719.14C 55 of 77 of success greater than 0.9. Those provisions include an assessment of the reliability of the disposal system and accounting for the possibility of damage to or cutting of the tether prior to disposal.

Compliance Statement: Compliant. Tethers are not being used. Furthermore, the rendezvous and proximity operations mission planned between Orbiter SN3 and Otter Pup is designed to address objective 5-3 in the 2019 ODMSP. Probability of collision is limited by designating Orbiter as a compliant docking target, which will hold an attitude throughout the approach and docking of Otter Pup.[4]

[4] *See* Starfish Space, Orbital Debris Assessment Report, ELS File No. 1117-EX-CN-2022 (filed Jan. 3. 2023).