I. OVERVIEW

Pursuant to Section 25.114 of the Commission's rules, Reflect Orbital herein provides a description of the design and operational strategies that will be used to mitigate orbital debris from the EARENDIL-1 spacecraft. This orbital debris assessment report was calculated using the National Aeronautics and Space Administration (NASA) Debris Assessment Software (DAS) version 3.2.6.

II. SATELLITE AND ORBITAL PARAMETERS

The spacecraft is a 142 kg spacecraft designed to reflect and aim a spot of sunlight onto a designated target on the ground with a deployable, highly specular 18 m x 18 m square thin-film reflector. In its stowed state, the vehicle measures 840.05 mm x 856.7 mm x 400 mm. In the deployed configuration, the vehicle measures 2439.59 mm x 18000 mm x 18000 mm.

The spacecraft will deploy the reflector in a highly-controlled, motorized, two-stage process prior to orbit-raising. In the first stage, a 4-boom composite structure is deployed that will provide the framing for the reflector. Once the composite structure is secured, the reflector will be deployed in the second stage and tensioned by cables running along the deployed structure.

The vehicle has two identical, redundant radios utilizing UHF, S-, and X-bands for telemetry, tracking, and command (TT&C) and data downlink. The spacecraft includes on-board propulsion for purposes of (1) orbit raising to the operational orbit, (2) orbital maintenance and collision avoidance during the operational mission, and (3) facilitating active deorbit at end of mission.

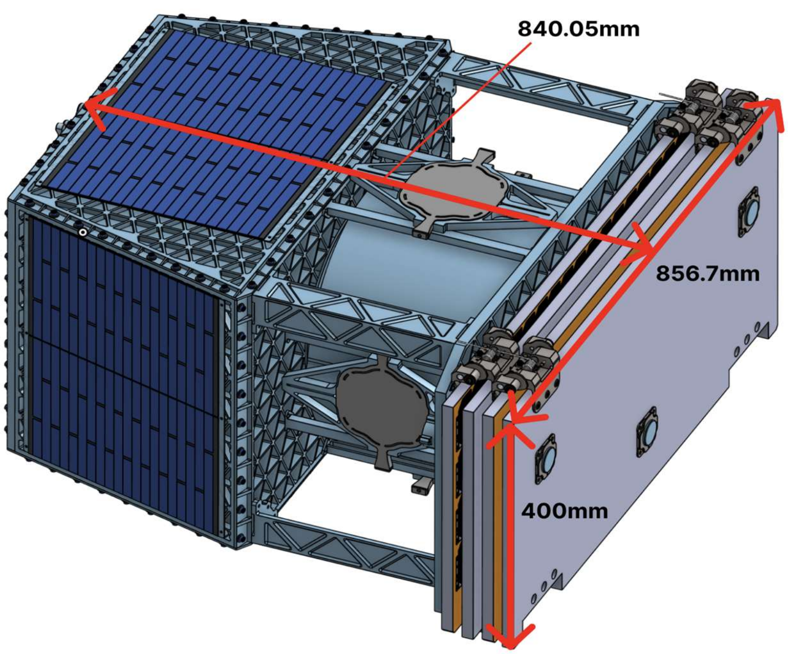

Figure 1: Stowed Configuration

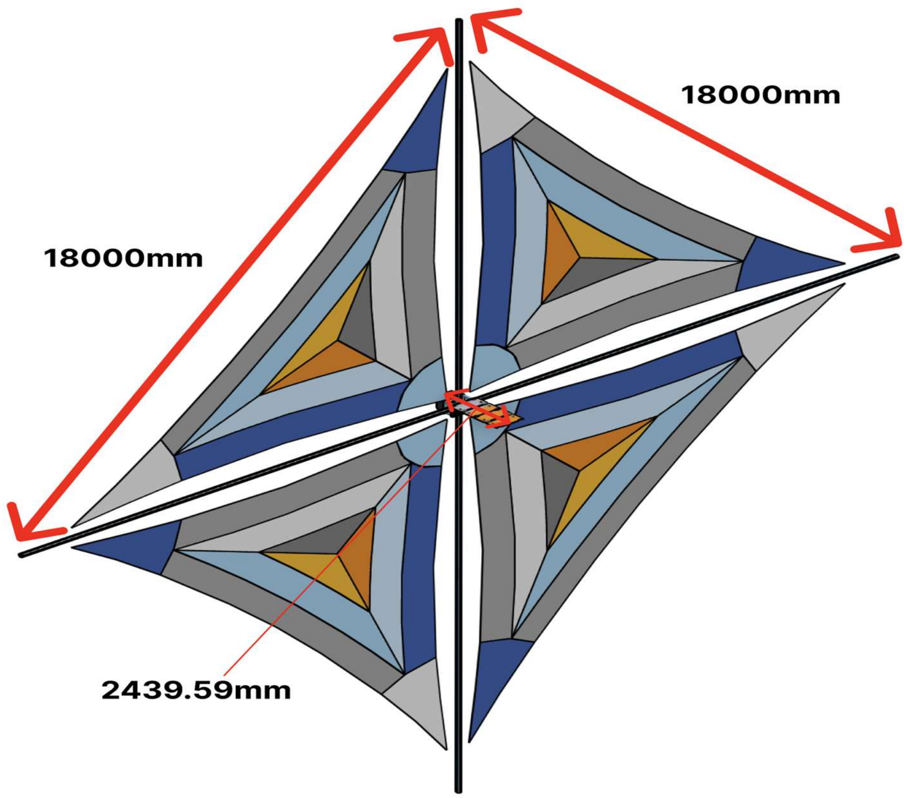

Figure 2: Deployed Configuration

III. SECTION 25.114(D)(14) COMPLIANCE

(i) A statement that the space station operator has assessed and limited the amount of debris released in a planned manner during normal operations. Where applicable, this statement must include an orbital debris mitigation disclosure for any separate deployment devices, distinct from the space station launch vehicle, that may become a source of orbital debris;

Reflect Orbital confirms that the satellite will not undergo any planned release of debris during normal operations. There are two planned deployment events during spacecraft commissioning: (1) the main solar array and (2) the heliostat. Both release mechanisms used to effectuate these deployments are commercial-off-the-shelf and designed to retain components as a nominal part of deployment.

Additionally, the spacecraft will be deployed from the launch vehicle using a debris-free actuator.

(ii) A statement indicating whether the space station operator has assessed and limited the probability that the space station(s) will become a source of debris by collision with small debris or meteoroids that would cause loss of control and prevent disposal. The statement must indicate whether this probability for an individual space station is 0.01 (1 in 100) or less, as calculated using the NASA Debris Assessment Software or a higher fidelity assessment tool;

Reflect Orbital has assessed the probability of the satellite becoming a debris source as a result of a collision with small debris or meteoroids of less than one centimeter in diameter that could cause loss of control and prevent post-mission disposal. Reflect Orbital has taken steps to limit the effects of such collisions to the spacecraft bus through structural shielding, the strategic placement of components interior to the bus, and the use of redundant systems on critical command and control capability. The largest cross section component of the spacecraft is the reflector itself, which is designed to be tolerant of micro-orbital debris strikes through a rip-stop design. In the event of a worst-case mirror strike, a mirror quadrant could tear fully across a panel, but all resultant components would remain attached to the vehicle due to the catenary cords.

No subsystems on-board the spacecraft are critical to effectuate safe and timely deorbit in accordance with the Commission's rules. From its operational orbit, the spacecraft will naturally demise within one year following the end of mission. Since there are no critical sub-systems for purposes of deorbit, Reflect Orbital conducted the small debris collision risk for a duration of 0.1 years, reflecting the time to complete the post-launch checkout and commissioning of EARENDIL-1, orbit raising to the operational altitude, and final deployment of the reflector. In this scenario, the probability of collision with small objects was computed to be 0.0015067, which is COMPLIANT with Section 25.114(d)(14)(ii) of the Commission's rules. Furthermore, in the event the heliostat does not fully or properly deploy during post-launch checkout and commissioning, Reflect Orbital will immediately lower the spacecraft to an altitude at which the spacecraft will naturally demise within five years.

(iii) A statement that the space station operator has assessed and limited the probability, during and after completion of mission operations, of accidental explosions or of release of liquids that will persist in droplet form. This statement must include a demonstration that debris generation will not result from the conversion of energy sources on board the spacecraft into energy that fragments the spacecraft. Energy sources include chemical, pressure, and kinetic energy. This demonstration should address whether stored energy will be removed at the spacecraft's end of life, by depleting residual fuel and leaving all fuel line valves open, venting any pressurized system, leaving all batteries in a permanent discharge state, and removing any remaining source of stored energy, or through other equivalent procedures specifically disclosed in the application;

Reflect Orbital designs its spacecraft in a manner that limits the probability of accidental explosion. As part of the satellite manufacturing process, Reflect Orbital takes steps to ensure that debris will not result from the conversion of energy sources onboard the satellites. The EARENDIL-1 spacecraft contains only the minimum viable sources of stored energy, with safeguards in place to deplete stored energy at end of life.

The EARENDIL-1 propulsion system utilizes a liquid hydrazine monopropellant, pressurized by helium. Hydrazine is a standard spacecraft monopropellant that remains stable when stored under appropriate conditions. The EARENDIL-1 propulsion system is low-pressure, blowdown system that operates at pressures below 450 psi in all cases and is specifically constructed from compatible materials. At the end of life, all remaining propellant will be depleted and all pressurant will be depressurized to safe levels to render it inert. To mitigate any risk of debris generating events, the propulsion system design ensures that residual helium pressure, after depletion of hydrazine, remains below the infinite safe fatigue life of the tank.

The batteries, momentum wheels, and propulsion system present the only plausible, albeit remote, causes for breakup of the satellite, which are:

1. Battery Explosion.

FAILURE MODE 1: Internal Short Circuit.

MITIGATION: Qualification and acceptance shock, vibration, thermal cycling, and vacuum tests followed by maximum system rate-limited charge and discharge to prove that no internal short circuit sensitivity exists.

COMBINED FAULTS REQUIRED FOR REALIZED FAILURE: Environmental testing AND functional charge/discharge tests must both be ineffective in discovery of the failure mode.

FAILURE MODE 2: Internal thermal rise due to high load discharge rate.

MITIGATION: Robust thermal design and over-current detection 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 a) qualification-tested short circuit protection on each external circuit, b) design of battery packs and insulators such that no contact with nearby board traces is possible without being caused by some other mechanical failure, c) 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 failure must all occur to enable this failure mode.

FAILURE MODE 4: Inoperable vents.

MITIGATION: Battery vents are not inhibited by the battery holder design or the spacecraft.

Combined Faults Required for Realized Failure: The final assembler fails to install proper venting.

<u>Failure Mode 5</u>: 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.

<u>Failure Mode 6</u>: 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 to result in this failure mode.

<u>Failure Mode 7</u>: 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 which are 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 overcurrent monitoring and control must all fail for this failure mode to occur.

2. Momentum Wheel Failure.

<u>Failure Mode 1</u>: Mechanical Failure.

Mitigation: Qualification and acceptance shock, vibration, thermal cycling, and vacuum tests followed by maximum spin rate testing. In the unlikely event of mechanical failure, the momentum wheel housing is designed to prevent any release of debris.

Combined Faults Required for Realized Failure: Environmental testing AND functional charge/discharge tests must both be ineffective in discovery of the failure mode AND the debris must have enough energy to puncture the momentum wheel housing and the bus structure.

3. Propulsion System Failure.

FAILURE MODE 1: Structural Damage of Main Propellant Tank.

MITIGATION: Qualification and acceptance shock, vibration, thermal, and hydrostatic tests at maximum allowable working pressures, followed by pressurized leak checks.

COMBINED FAULTS REQUIRED FOR REALIZED FAILURE: Environmental testing, hydrostatic, AND leak check tests are all ineffective in discovery of the failure mode.

FAILURE MODE 2: Overpressure due to decomposition of hydrazine.

MITIGATION: Hydrazine is maintained at temperatures below 60° C using insulation where necessary to prevent boiling from occurring. Thermal analysis is conducted to verify the insulation. Hydrazine flow velocity is maintained below 4 mm/s, reducing the kinetic energy of the fluid. All systems in contact with hydrazine are cleaned for hydrazine pursuant to MIL-STD-1774.

COMBINED FAULTS REQUIRED FOR REALIZED FAILURE: Thermal analysis AND insulation testing prove ineffective in discovery of failure mode AND hydrazine heats to phase change.

FAILURE MODE 3: Electrical discharge to fluid system.

MITIGATION: High voltage components which could arc to propulsion system components are isolated via enclosures and distance determined by breakdown voltage analysis. Enclosures are tested to ensure that seals are sufficient.

COMBINED FAULTS REQUIRED FOR REALIZED FAILURE: Breakdown volage analysis AND seal check tests prove ineffective in discovery of failure mode AND arc path travels through a component containing hydrazine.

FAILURE MODE 4: Mechanical rupture to propellant systems due to external force.

MITIGATION: Integrated vehicle qualification and acceptance testing, shock, vibration, and thermal testing, followed by leak check tests.

COMBINED FAULTS REQUIRED FOR REALIZED FAILURE: Integrated vehicle testing AND environmental testing AND leak check tests prove ineffective in discovery of failure mode AND external force must puncture a component containing hydrazine.

FAILURE MODE 5: Propellant feed system stuck on, leading to mechanical failure.

MITIGATION: Propulsion system is rated to discharge all propellant in a single firing. Redundant isolation valves are used in-line with the thruster main valve such that fluid may only flow when all three valves are open. Leak checks are performed on ground, ensuring no flow path is present when any single valve is closed. Environmental testing is performed on the propulsion controller, then valve dry clicks are performed to ensure no degradation in performance.

COMBINED FAULTS REQUIRED FOR REALIZED FAILURE: Propulsion system qualification data is not representative AND leak checks prove ineffective in discovery of failure mode AND all three valves in series fail to close when commanded, leaving the thruster firing. The propulsion controller is stuck in the ON configuration, providing the valves with power even when commanded off.

(iv) A statement that the space station operator has assessed and limited the probability of the space station(s) becoming a source of debris by collisions with large debris or other operational space stations.

Reflect Orbital has assessed and limited the probability of the satellite becoming a debris source through collision with large debris or other operational space stations. The probability of a collision of the EARENDIL-1 spacecraft with an orbiting object larger than 10 cm in diameter was calculated using NASA's DAS 3.2.6 software and provided in the responses below.

(A) Where the application is for an NGSO space station or system, the following information must also be included:

(1) A demonstration that the space station operator has assessed and limited the probability of collision between any space station of the system and other large objects (10 cm or larger in diameter) during the total orbital lifetime of the space station, including any de-orbit phases, to less than 0.001 (1 in 1,000). The probability shall be calculated using the NASA Debris Assessment Software or a higher fidelity assessment tool. The collision risk may be assumed zero for a space station during any period in which the space station will be maneuvered effectively to avoid colliding with large objects.

The EARENDIL-1 spacecraft includes a propulsion capability that will be employed to support collision avoidance maneuvers; therefore, the collision risk can be assumed to be zero.

(2) The statement must identify characteristics of the space station(s)' orbits that may present a collision risk, including any planned and/or operational space stations in those orbits, and indicate what steps, if any, have been taken to coordinate with the other spacecraft or system, or what other measures the operator plans to use to avoid collision.

Reflect Orbital acknowledges that other spacecraft operators are authorized at or below the nominal orbital altitude range in which the EARENDIL-1 spacecraft will operate, as published in the FCC Approved Space Station List or ITU SpaceExplorer Database. Reflect Orbital will coordinate with these operators, as required, to minimize collision risk during all phases of operation.

(3) If at any time during the space station(s)' mission or de-orbit phase the space station(s) will transit through the orbits used by any inhabitable spacecraft, including the International Space Station, the statement must describe the design and operational strategies, if any, that will be used to minimize the risk of collision and avoid posing any operational constraints to the inhabitable spacecraft.

At launch, Reflect Orbital will work closely with its launch provider to minimize the potential for in-plane collision, specifically minimizing the potential for collision with crewed spacecraft.

During the operational lifetime of the spacecraft, Reflect Orbital operates above the orbital altitudes of all existing inhabited spacecraft. Reflect Orbital remains diligent and, where necessary, can minimize risk of collision or placement of operational constraints on inhabitable spacecraft through collision avoidance measures and conjunction alerts that are monitored 24/7 by the Reflect Orbital operations team.

At end of life, planned disposal for the EARENDIL-1 spacecraft will occur via a combination of active and passive deorbit maneuvers. Reflect Orbital will coordinate with NASA and other relevant administrations prior to descent through the orbits of the International Space Station, Tiangong space station, and any other crewed spacecraft to minimize the risk of collision avoidance calculations. Following such coordination, the satellite's circular orbit altitude will be lowered below that of any habitable space station to ensure expedient and complete demise. The EARENDIL-1 propulsion capability can be used during its end-of-life operations, to extent appropriate, to facilitate this safe and expedient deorbit. Once the spacecraft has been lowered below the lower bound of the control authority of the crewed spacecraft and approaches an altitude where attitude control can no longer be maintained, the satellite will perform a final orienting maneuver before depleting any remaining propellant and passivating all systems.

> *(4) The statement must disclose the accuracy, if any, with which orbital parameters will be maintained, including apogee, perigee, inclination, and the right ascension of the ascending node(s). In the event that a system is not able to maintain orbital tolerances, e.g., its propulsion system will not be used for orbital maintenance, that fact must be included in the debris mitigation disclosure. Such systems must also indicate the anticipated evolution over time of the orbit of the proposed satellite or satellites. All systems must describe the extent of satellite maneuverability, whether or not the space station design includes a propulsion system.*

The satellite will maintain orbital tolerances, including apogee, perigee, inclination, and right ascension, with the following degree of accuracy:

Operational Orbit	Nominal Values	Tolerances
Apogee (km)	625	+/- 25 km
Perigee (km)	625	+/- 25 km
Inclination (degrees)	88.0	+/- 2.0 deg
MLTAN	N/A	N/A

The satellite will maintain orbital tolerances using a chemical propulsion system and an attitude and orbit control system (AOCS). The satellite has three 12 Nms reaction wheels oriented orthogonally to provide three axis control, in addition to three orthogonal magnetorquers to desaturate the reaction wheels. The reaction system can be used to orient the propulsion system to vector the satellite's thrust relative to its velocity vector, enabling the satellite to raise, lower, correct, and maintain its orbit.

PROPULSION. Propulsion will initially be used to raise the satellite altitude from its insertion orbit to its operational orbit following checkout and commissioning. During the operational mission, propulsion will be used to maintain altitude and to conduct collision avoidance maneuvers, as necessary. At end of life, to the extent any propellant remains, propulsion will be used to lower the spacecraft altitude to expedite safe demise.

The satellite has a hydrazine monopropellant propulsion system with space-rated TRL 9 valves and a single commercial-off-the-shelf main thruster. The propellant tank is a custom titanium diaphragm tank. The propulsion system utilizes all welded construction in compliance with AF-SPCMAN-91-710, isolation values with space heritage, and the following characteristics:

Parameter	Value
Thrust	4N
Impulse Bit	0.04 Ns
Total Impulse	24 kNs
Max. Pulse Rate	100 Hz

ATTITUDE DETERMINATION AND CONTROL SYSTEM (ADCS). The spacecraft also includes an ADCS that can achieve pointing accuracy up to 7 arc-seconds and a slew rate capability of 3°/s in all directions during nominal mission operations. The ADCS system consists of a Global Navigation Satellite System receiver, an Inertial Measurement Unit, two star trackers, three reaction wheels, and three magnetorquers.

> *(5) The space station operator must certify that upon receipt of a space situational awareness conjunction warning, the 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.*

Reflect Orbital minimizes the risk of collision and avoids operational constraints through collision avoidance measures and conjunction alerts that are monitored 24/7 by the Reflect Orbital operations team. The operations team also works with a third-party company to assist in conjunction analysis and collision avoidance maneuver planning. In the event of an alert, Reflect Orbital will monitor and evaluate conjunctions warnings, coordinate with 18th Space Defense Squadron (18SDS) and other potentially impacted operators, and determine if an avoidance maneuver is required or the conjunction risk will resolve itself. If alerted to an event, Reflect Orbital operations will manually add a maneuver to the schedule based on the outputs from coordination activities. If active maneuvers are required to avoid a collision, the EARENDIL-1 spacecraft can achieve a 1 m/s delta-V maneuver in under 60 seconds.

Reflect Orbital will engage with any operators of nearby constellations and other space stations to ensure safe and coordinated space operations. Reflect Orbital will also provide all relevant U.S. agencies with any information they need to assess risks and ensure safe flight profiles, as well as contact information for Reflect Orbital Mission Operations Center personnel.

(B) Where a space station requests the assignment of a geostationary orbit location, it must assess whether there are any known satellites located at, or reasonably expected to be located at, the requested orbital location, or assigned in the vicinity of that location, such that the station keeping volumes of the respective satellites might overlap or touch. If so, the statement must include a statement as to the identities of those satellites and the measures that will be taken to prevent collisions;

N/A.

(v) A statement addressing the trackability of the space station(s). Space station(s) operating in low-Earth orbit will be presumed trackable if each individual space station is 10 cm or larger in its smallest dimension, excluding deployable components. Where the application is for an NGSO space station or system, the statement shall also disclose the following:

(A) How the operator plans to identify the space station(s) following deployment and whether space station tracking will be active or passive;

The spacecraft is presumed trackable. The smallest dimension of the EARENDIL-1 spacecraft, in its stowed configuration is ~40.0 cm.

Reflect Orbital will employ both active and passive tracking measures.

ACTIVE. After deployment, Reflect Orbital will actively track its spacecraft utilizing a unique telemetry marker to assure the spacecraft can be identified. Such active tracking will be in conformance with the radiofrequency parameters in this Application. Reflect Orbital will maintain a complete and accurate set of current and planned radiofrequency transmissions for its spacecraft and will provide any necessary technical information to other operators to identify and promptly resolve any potential radiofrequency interference between systems.

PASSIVE. Reflect Orbital has a space situational awareness (SSA) agreement with U.S. Space Command and also leverages the 18SDS automatic notification system (provided via SpaceTrack.org) to maximize situational awareness and coordinate as necessary with other operators. Reflect Orbital Mission Operations uses the NORAD Satellite Catalog and other publicly available sources to passively monitor the location of the satellites using the two-line elements, as well as Global Positioning System modules, in order to propagate trajectories of the spacecraft to enhance the quality of conjunction predictions with other space stations.

(B) Whether, prior to deployment, the space station(s) will be registered with the 18th Space Control Squadron or successor entity; and

Reflect Orbital will register the spacecraft with the 18SDS (or the appropriate successor entity) and will share information regarding initial spacecraft deployment, ephemeris, and planned maneuver information.

(C) The extent to which the space station operator plans to share information regarding initial deployment, ephemeris, and/or planned maneuvers with the 18th Space Control Squadron or successor entity, other entities that engage in space situational awareness or space traffic management functions, and/or other operators.

Reflect Orbital uses validated commercial conjunction assessment services to augment the information it receives from the 18SDS and U.S. Space Command. Where appropriate, Reflect Orbital will keep up to date spacecraft ephemeris in the database by uploading predictive and mission planning ephemeris for review by the 18SDS through the website or email communication.

The 18SDS can contact the Reflect Orbital Mission Operations team twenty-four hours a day, seven days per week to ensure that Reflect Orbital can take immediate action to coordinate collision avoidance measures. Reflect Orbital will engage with any operators of nearby constellations and other space stations to ensure safe and coordinated space operations.

(vi) A statement disclosing planned proximity operations, if any, and addressing debris generation that will or may result from the proposed operations, including any planned release of debris, the risk of accidental explosions, the risk of accidental collision, and measures taken to mitigate those risks.

N/A.

(vii) A statement detailing the disposal plans for the space station, including the quantity of fuel—if any—that will be reserved for disposal maneuvers. In addition, the following specific provisions apply:

(A) For geostationary orbit space stations, the statement must disclose the altitude selected for a disposal orbit and the calculations that are used in deriving the disposal altitude.

N/A.

(B) For space stations terminating operations in an orbit in or passing through the low-Earth orbit region below 2,000 km altitude, the statement must disclose whether the spacecraft will be disposed of through atmospheric re-entry, specifying if direct retrieval of the spacecraft will be used. The statement must also disclose the expected time in orbit for the space station following the completion of the mission.

Reflect Orbital will dispose of the satellites by atmospheric re-entry. The expected mission lifetime is approximately 1 year. The expected post-mission lifetime is less than one year without using propulsion or drag to expedite lowering. The figure below illustrates the passive deorbit time from the maximum operational orbit of 650 km starting in ~ June 2027, after one year of operations.

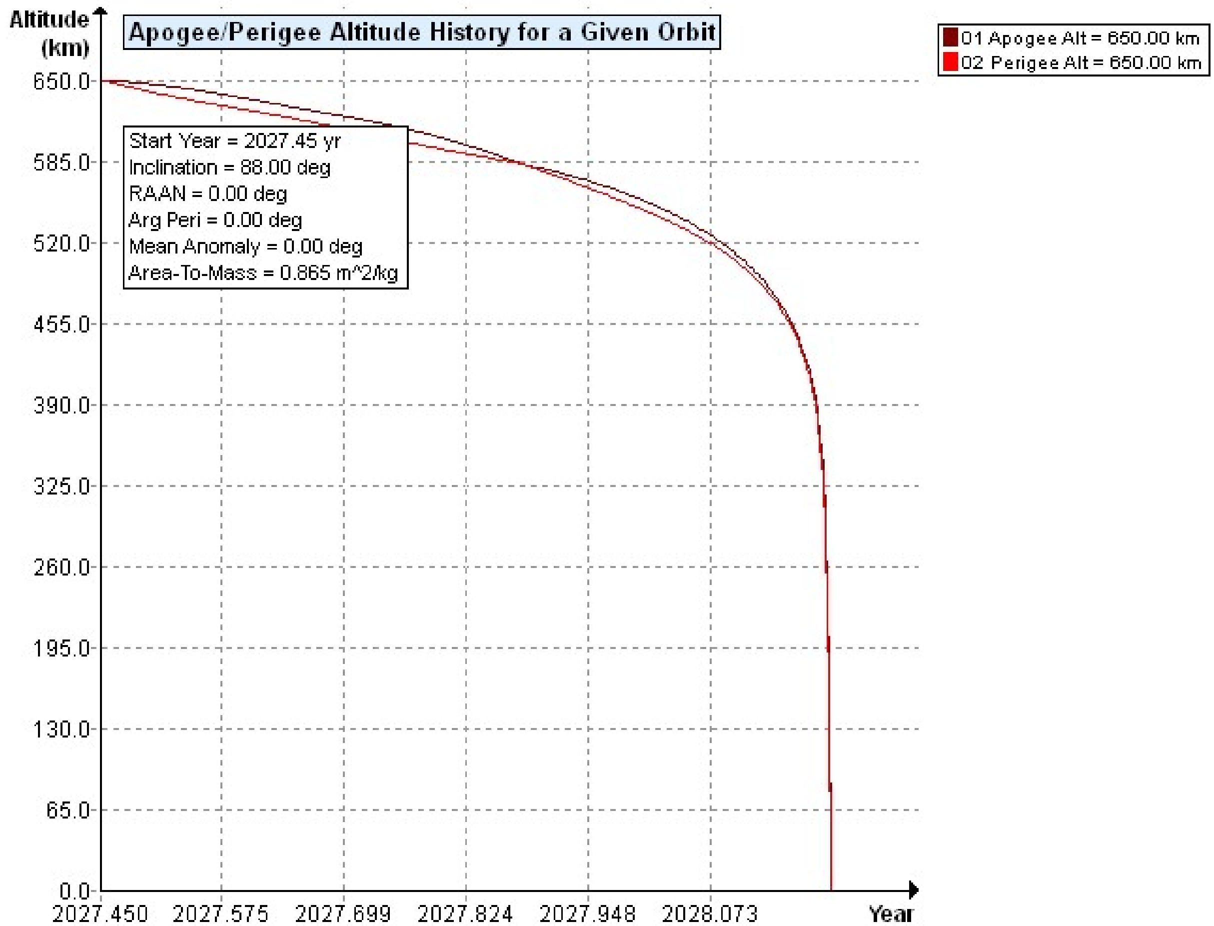

Figure 3 Passive Deorbit Profile from Maximum Orbit Altitude at End of Mission

(C) For space stations not covered by either paragraph (d)(14)(vii)(A) or (B) of this section, the statement must indicate whether disposal will involve use of a storage orbit or long-term atmospheric re-entry and rationale for the selected disposal plan.

N/A.

(D) For all space stations under paragraph (d)(14)(vii) (B) or (C) of this section, the following additional specific provisions apply:

(1) The statement must include a demonstration that the probability of success of the chosen disposal method will be 0.9 or greater for any individual space station. For space station systems consisting of multiple space stations, the demonstration should include additional information regarding efforts to achieve a higher probability of success, with a goal, for large systems, of a probability of success for any individual space station of 0.99 or better. For space stations under paragraph (d)(14)(vii)(B) of this section ending their mission in or passing through the low-Earth orbit region below 2000 km altitude, successful disposal is defined, for the purposes of this paragraph (d)(14)(vii)(D)(1), as atmospheric re-entry of the spacecraft as soon as practicable, but no later than five years following completion of the mission. For all other space stations under paragraphs (d)(14)(vii)(B) and (C) of this section, successful disposal will be assessed on a case-by-case basis.

As demonstrated in Figure 3 above, upon the successful completion of checkout and commissioning, the EARENDIL-1 spacecraft will naturally demise in less than five years at all mission altitudes absent propulsive maneuvers to sustain the orbit. Thus, the satellite has a high probability of successfully deorbiting through its chosen method.

(2) If planned disposal is by atmospheric re-entry, the statement must also include:

(i) A disclosure indicating whether the atmospheric re-entry will be an uncontrolled re-entry or a controlled targeted re-entry.

Re-entry will be uncontrolled.

(ii) An assessment as to whether portions of any individual spacecraft will survive atmospheric re-entry and impact the surface of the Earth with a kinetic energy in excess of 15 joules, and demonstration that the calculated casualty risk for an individual spacecraft using the NASA Debris Assessment Software or a higher fidelity assessment tool is less than 0.0001 (1 in 10,000).

DAS analysis suggests that the Titanium propellant tank has the potential to survive re-entry with total debris casualty area of 0.7 m^2 and a kinetic energy of 2544 joules. Based upon these simulation results, the risk of human casualty is 1:119,400. Alternate propellant tanks materials were considered but the only viable options identified were Titanium or a Carbon Fiber wrapped pressure vessels (COPV). The latter option was eliminated due to recent NASA concerns regarding the survivability of COPV relative to DAS modeling. Thus, the current propellant tank was selected for its material compatibility with the hydrazine fuel used onboard the spacecraft, as well as the lead time for which it was available for integration and testing on the ground.

No other components expected to survive re-entry.

(E) Applicants for space stations to be used only for commercial remote sensing may, in lieu of submitting detailed post-mission disposal plans to the Commission, certify that they have submitted such plans to the National Oceanic and Atmospheric Administration for review.

N/A.

(viii) For non-U.S.-licensed space stations, the requirement to describe the design and operational strategies to minimize orbital debris risk can be satisfied by demonstrating that debris mitigation plans for the space station(s) for which U.S. market access is requested are subject to direct and effective regulatory oversight by the national licensing authority.

N/A.

DAS 3.2.6 LOG

07 30 2025; 09:27:54AM Project Data Saved To File

07 30 2025; 09:28:02AM Processing Requirement 4.3-1: Return Status : Not Run

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No Project Data Available

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=============== End of Requirement 4.3-1 ===============

07 30 2025; 09:28:04AM Processing Requirement 4.3-2: Return Status : Passed

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No Project Data Available

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

07 30 2025; 09:29:36AM Processing Requirement 4.5-1: Return Status : Passed

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Run Data

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

INPUT

Space Structure Name = EARENDIL-1

Space Structure Type = Payload

Perigee Altitude = 625.000 (km)

Apogee Altitude = 625.000 (km)

Inclination = 88.000 (deg)

RAAN = 0.000 (deg)

Argument of Perigee = 0.000 (deg)

Mean Anomaly = 0.000 (deg)

Final Area-To-Mass Ratio = 0.8649 (m^2/kg)

Start Year = 2026.350 (yr)

Initial Mass = 142.000 (kg)

Final Mass = 129.000 (kg)

Duration = 1.000 (yr)

Station-Kept = False

Abandoned = True

Long-Term Reentry = False

OUTPUT

Collision Probability = 1.3141E-04

Returned Message: Normal Processing

Date Range Message: Normal Date Range

Status = Pass

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

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

07 30 2025; 09:30:27AM Project Data Saved To File

07 30 2025; 09:32:12AM Requirement 4.5-2: Compliant

==

Spacecraft = EARENDIL-1 _Small Obj

Critical Surface = Electronics

==

INPUT

Apogee Altitude = 550.000 (km)

Perigee Altitude = 550.000 (km)

Orbital Inclination = 88.000 (deg)

RAAN = 0.000 (deg)

Argument of Perigee = 0.000 (deg)

Mean Anomaly = 0.000 (deg)

Final Area-To-Mass = 0.0108 (m^2/kg)

Initial Mass = 129.000 (kg)

Final Mass = 129.000 (kg)

Station Kept = No

Start Year = 2026.350 (yr)

Duration = 0.100 (yr)

Orientation = Random Tumbling

CS Areal Density = 0.270 (g/cm^2)

CS Surface Area = 0.1000 (m^2)

Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))

CS Pressurized = No

Outer Wall 1   Density: 0.540 (g/cm^2) Separation: 1.000 (cm)

Outer Wall 2   Density: 0.270 (g/cm^2) Separation: 10.000 (cm)

OUTPUT

Probability of Penetration = 2.6571E-04 (2.6575E-04)

Returned Error Message: Normal Processing

Date Range Error Message: Normal Date Range

===

Spacecraft = EARENDIL-1 _Small Obj

Critical Surface = Propellant Tank

===

INPUT

Apogee Altitude = 550.000 (km)

Perigee Altitude = 550.000 (km)

Orbital Inclination = 88.000 (deg)

RAAN = 0.000 (deg)

Argument of Perigee = 0.000 (deg)

Mean Anomaly = 0.000 (deg)

Final Area-To-Mass = 0.0108 (m^2/kg)

Initial Mass = 129.000 (kg)

Final Mass = 129.000 (kg)

Station Kept = No

Start Year = 2026.350 (yr)

Duration = 0.100 (yr)

Orientation = Random Tumbling

CS Areal Density = 0.400 (g/cm^2)

CS Surface Area = 0.0670 (m^2)

Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))

CS Pressurized = Yes

Outer Wall 1   Density: 0.270 (g/cm^2) Separation: 10.000 (cm)

OUTPUT

Probability of Penetration = 1.5067E-03 (1.5079E-03)

Returned Error Message: Normal Processing

Date Range Error Message: Normal Date Range

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

07 30 2025; 09:32:41AM   Processing Requirement 4.6   Return Status : Passed

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

Project Data

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INPUT

Space Structure Name = EARENDIL-1

Space Structure Type = Payload

Perigee Altitude = 625.000000 (km)

Apogee Altitude = 625.000000 (km)

Inclination = 88.000000 (deg)

RAAN = 0.000000 (deg)

Argument of Perigee = 0.000000 (deg)

Mean Anomaly = 0.000000 (deg)

Area-To-Mass Ratio = 0.864945 (m^2/kg)

Start Year = 2026.350000 (yr)

Initial Mass = 142.000000 (kg)

Final Mass = 129.000000 (kg)

Duration = 1.000000 (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 = 625.000000 (km)

Suggested Apogee Altitude = 625.000000 (km)

Returned Error Message = Reentry during mission (no PMD req.).

Released Year = 2026 (yr)

Requirement = 61

Compliance Status = Pass

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

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

07 30 2025; 09:32:48AM *********Processing Requirement 4.7-1

Return Status : Passed

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

Item Number = 1

name = EARENDIL-1

quantity = 1

parent = 0

materialID = 8

type = Box

Aero Mass = 129.000000

Thermal Mass = 129.000000

Diameter/Width = 0.711000

Length = 0.766000

Height = 0.461000

name = Aft Plate

quantity = 1

parent = 1

materialID = 8

type = Flat Plate

Aero Mass = 75.698001

Thermal Mass = 2.410000

Diameter/Width = 0.488951

Length = 0.488951

name = Mid Plate

quantity = 1

parent = 2

materialID = 8

type = Flat Plate

Aero Mass = 73.048001

Thermal Mass = 3.640000

Diameter/Width = 0.457000

Length = 0.711000

name = X RW4-12

quantity = 1

parent = 3

materialID = 8

type = Box

Aero Mass = 5.000000

Thermal Mass = 5.000000

Diameter/Width = 0.254000

Length = 0.254000

Height = 0.076000

name = Flight Computer

quantity = 1

parent = 3

materialID = 8

type = Box

Aero Mass = 2.000000

Thermal Mass = 2.000000

Diameter/Width = 0.177800

Length = 0.254001

Height = 0.050800

name = Payload Controller

quantity = 1

parent = 3

materialID = 8

type = Box

Aero Mass = 2.000000

Thermal Mass = 2.000000

Diameter/Width = 0.177800

Length = 0.254001

Height = 0.050800

name = Drum

quantity = 1

parent = 3

materialID = 8

type = Cylinder

Aero Mass = 22.060000

Thermal Mass = 1.270000

Diameter/Width = 0.279401

Length = 0.292101

name = Top Plate

quantity = 1

parent = 7

materialID = 8

type = Flat Plate

Aero Mass = 11.640000

Thermal Mass = 3.640000

Diameter/Width = 0.457201

Length = 0.711201

name = Solar Wing Assembly

quantity = 4

parent = 8

materialID = -1

type = Box

Aero Mass = 2.000000

Thermal Mass = 2.000000

Diameter/Width = 0.460000

Length = 0.860000

Height = 0.012700

name = Surfboard

quantity = 1

parent = 7

materialID = 8

type = Flat Plate

Aero Mass = 9.150000

Thermal Mass = 1.150000

Diameter/Width = 0.279401

Length = 0.279401

name = PDU

quantity = 1

parent = 10

materialID = 8

type = Box

Aero Mass = 4.000000

Thermal Mass = 4.000000

Diameter/Width = 0.152400

Length = 0.254001

Height = 0.101600

name = Battery

quantity = 1

parent = 10

materialID = 8

type = Box

Aero Mass = 4.000000

Thermal Mass = 4.000000

Diameter/Width = 0.152400

Length = 0.254001

Height = 0.101600

name = Boom Seat

quantity = 4

parent = 3

materialID = 8

type = Flat Plate

Aero Mass = 3.807000

Thermal Mass = 0.407000

Diameter/Width = 0.152400

Length = 0.292101

name = Mast Head

quantity = 4

parent = 13

materialID = 8

type = Flat Plate

Aero Mass = 0.200000

Thermal Mass = 0.200000

Diameter/Width = 0.152400

Length = 0.292101

name = Deployable Booms

quantity = 4

parent = 13

materialID = -1

type = Cylinder

Aero Mass = 3.200000

Thermal Mass = 3.200000

Diameter/Width = 0.152400

Length = 12.700026

name = Motor Assembly

quantity = 16

parent = 3

materialID = 54

type = Cylinder

Aero Mass = 1.240000

Thermal Mass = 1.240000

Diameter/Width = 0.070000

Length = 0.180000

name = Reflector Box

quantity = 4

parent = 3

materialID = -1

type = Box

Aero Mass = 0.400000

Thermal Mass = 0.400000

Diameter/Width = 0.254001

Length = 0.292101

Height = 0.152400

name = Antennas

quantity = 8

parent = 3

materialID = -1

type = Flat Plate

Aero Mass = 0.060000

Thermal Mass = 0.060000

Diameter/Width = 0.101600

Length = 0.101600

name = Camera System

quantity = 2

parent = 3

materialID = 8

type = Box

Aero Mass = 0.600000

Thermal Mass = 0.600000

Diameter/Width = 0.101600

Length = 0.254001

Height = 0.050800

name = MTQ Control Box

quantity = 3

parent = 2

materialID = 8

type = Box

Aero Mass = 0.080000

Thermal Mass = 0.080000

Diameter/Width = 0.076200

Length = 0.076200

Height = 0.012700

name = -Z Trapezoid Panel

quantity = 1

parent = 1

materialID = 8

type = Flat Plate

Aero Mass = 4.200000

Thermal Mass = 2.450000

Diameter/Width = 0.381000

Length = 0.660000

name = USX Radio #1

quantity = 1

parent = 21

materialID = 8

type = Box

Aero Mass = 1.750000

Thermal Mass = 1.750000

Diameter/Width = 0.175260

Length = 0.236220

Height = 0.031750

name = +Z Trapezoid Panel

quantity = 1

parent = 1

materialID = 8

type = Flat Plate

Aero Mass = 9.200000

Thermal Mass = 2.450000

Diameter/Width = 0.381000

Length = 0.660000

name = Z RW4-12

quantity = 1

parent = 23

materialID = 8

type = Box

Aero Mass = 5.000000

Thermal Mass = 5.000000

Diameter/Width = 0.254000

Length = 0.254000

Height = 0.076000

name = USX Radio #2

quantity = 1

parent = 23

materialID = 8

type = Box

Aero Mass = 1.750000

Thermal Mass = 1.750000

Diameter/Width = 0.175260

Length = 0.236220

Height = 0.031750

name = -Y Side Plate

quantity = 1

parent = 1

materialID = 8

type = Flat Plate

Aero Mass = 1.823000

Thermal Mass = 1.823000

Diameter/Width = 0.399000

Length = 0.437000

name = +Y Side Plate

quantity = 1

parent = 1

materialID = 8

type = Flat Plate

Aero Mass = 8.723000

Thermal Mass = 1.823000

Diameter/Width = 0.399000

Length = 0.437000

name = Y RW Bracket

quantity = 1

parent = 27

materialID = 8

type = Box

Aero Mass = 5.150000

Thermal Mass = 0.150000

Diameter/Width = 0.030000

Length = 0.100000

Height = 0.030000

name = Y RW4-12

quantity = 1

parent = 28

materialID = 8

type = Box

Aero Mass = 5.000000

Thermal Mass = 5.000000

Diameter/Width = 0.254000

Length = 0.254000

Height = 0.076000

name = Ethernet Switch

quantity = 1

parent = 27

materialID = 8

type = Box

Aero Mass = 0.490000

Thermal Mass = 0.490000

Diameter/Width = 0.101600

Length = 0.101600

Height = 0.050800

name = MTQ 800 Magnetorquers

quantity = 3

parent = 27

materialID = 19

type = Cylinder

Aero Mass = 0.420000

Thermal Mass = 0.420000

Diameter/Width = 0.038100

Length = 0.254001

name = Propulsion Panel

quantity = 1

parent = 1

materialID = 8

type = Flat Plate

Aero Mass = 2.180000

Thermal Mass = 0.600000

Diameter/Width = 0.100000

Length = 0.343000

name = Star Tracker Bracket

quantity = 2

parent = 32

materialID = 8

type = Box

Aero Mass = 0.490000

Thermal Mass = 0.220000

Diameter/Width = 0.093980

Length = 0.127000

Height = 0.093980

name = ST16HV Large Baffle Star Tracker

quantity = 2

parent = 33

materialID = 8

type = Box

Aero Mass = 0.270000

Thermal Mass = 0.270000

Diameter/Width = 0.093980

Length = 0.127000

Height = 0.093980

name = Fill/Drain Valves

quantity = 2

parent = 32

materialID = 54

type = Cylinder

Aero Mass = 0.150000

Thermal Mass = 0.150000

Diameter/Width = 0.038100

Length = 0.076200

name = Thruster

quantity = 1

parent = 32

materialID = 54

type = Cylinder

Aero Mass = 0.300000

Thermal Mass = 0.300000

Diameter/Width = 0.038100

Length = 0.101600

name = Tank Bracket

quantity = 7

parent = 1

materialID = 8

type = Box

Aero Mass = 1.624857

Thermal Mass = 1.021000

Diameter/Width = 0.381000

Length = 0.381000

Height = 0.076000

name = MV020 Valve

quantity = 2

parent = 37

materialID = 54

type = Cylinder

Aero Mass = 0.576000

Thermal Mass = 0.576000

Diameter/Width = 0.100000

Length = 0.050000

name = Titanium Diaphragm Tank

quantity = 1

parent = 37

materialID = 65

type = Sphere

Aero Mass = 3.044000

Thermal Mass = 3.000000

Diameter/Width = 0.292101

name = Helium Tube

quantity = 1

parent = 39

materialID = 54

type = Cylinder

Aero Mass = 0.044000

Thermal Mass = 0.044000

Diameter/Width = 0.006350

Length = 0.406401

name = Propellant Tube Run with Tees

quantity = 1

parent = 37

materialID = 54

type = Cylinder

Aero Mass = 0.031000

Thermal Mass = 0.031000

Diameter/Width = 0.006350

Length = 0.304801

name = Carbonix C15 Deployer Ring

quantity = 1

parent = 1

materialID = 8

type = Flat Plate

Aero Mass = 0.600000

Thermal Mass = 0.600000

Diameter/Width = 0.381001

Length = 0.381001

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

Item Number = 1

name = EARENDIL-1

Demise Altitude = 77.998621

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Aft Plate

Demise Altitude = 77.160845

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Mid Plate

Demise Altitude = 76.282992

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = X RW4-12

Demise Altitude = 73.150655

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Flight Computer

Demise Altitude = 74.697227

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Payload Controller

Demise Altitude = 74.697227

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Drum

Demise Altitude = 75.729226

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Top Plate

Demise Altitude = 74.860609

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Solar Wing Assembly

Demise Altitude = 74.386087

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Surfboard

Demise Altitude = 74.869511

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = PDU

Demise Altitude = 72.396892

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Battery

Demise Altitude = 72.396892

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Boom Seat

Demise Altitude = 75.864699

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Mast Head

Demise Altitude = 75.653031

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Deployable Booms

Demise Altitude = 75.807494

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Motor Assembly

Demise Altitude = 67.849478

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Reflector Box

Demise Altitude = 76.093211

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Antennas

Demise Altitude = 76.038557

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Camera System

Demise Altitude = 75.684643

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = MTQ Control Box

Demise Altitude = 76.774024

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = -Z Trapezoid Panel

Demise Altitude = 77.247972

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = USX Radio #1

Demise Altitude = 75.342946

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = +Z Trapezoid Panel

Demise Altitude = 77.261460

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Z RW4-12

Demise Altitude = 73.873844

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = USX Radio #2

Demise Altitude = 75.472277

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = -Y Side Plate

Demise Altitude = 77.167234

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = +Y Side Plate

Demise Altitude = 77.209052

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Y RW Bracket

Demise Altitude = 76.547720

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Y RW4-12

Demise Altitude = 73.272483

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Ethernet Switch

Demise Altitude = 76.077451

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = MTQ 800 Magnetorquers

Demise Altitude = 75.007871

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Propulsion Panel

Demise Altitude = 77.202867

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Star Tracker Bracket

Demise Altitude = 76.890967

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = ST16HV Large Baffle Star Tracker

Demise Altitude = 76.500073

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Fill/Drain Valves

Demise Altitude = 73.360602

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Thruster

Demise Altitude = 71.429138

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Tank Bracket

Demise Altitude = 77.582718

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = MV020 Valve

Demise Altitude = 69.287036

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Titanium Diaphragm Tank

Demise Altitude = 0.000000

Debris Casualty Area = 0.704280

Impact Kinetic Energy = 2543.816723

****

name = Helium Tube

Demise Altitude = 0.000000

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Propellant Tube Run with Tees

Demise Altitude = 76.800633

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Carbonix C15 Deployer Ring

Demise Altitude = 77.680621

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

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

07 30 2025; 09:32:48AM Project Data Saved To File