STARCLOUD ORBITAL DATA CENTER SYSTEM

ATTACHMENT B

Orbital Debris Assessment Report (ODAR)

Document Scope

Starcloud's orbital debris mitigation plan for its Orbital Datacenter System is presented below in the format recommended by the commission. Starcloud's approach emphasizes designing the system to be actively controllable throughout its life, highly trackable and transparent to other operators, and reliably disposable at end of mission.

ODAR Summary Table

Mission Overview and Spacecraft Information	
A statement describing the extent of satellite maneuverability, including whether or not the space station design includes a propulsion system. §25.114(d)(14)(iv)(A)(4). Indicate the components required for the propulsion system to operate reliably, including communications with the satellite.	Each satellite will have Starcloud's low complexity triple redundant propulsion systems with sufficient propellant and performance for orbit raising during commissioning, station-keeping including collision avoidance maneuvers, and complete disposal via atmospheric reentry with significant margin.
A statement describing the accuracy, if any, with which orbital parameters will be maintained, including apogee, perigee, inclination, and the right ascension of the ascending node(s). If 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. § 25.114(d)(14)(iv)(A)(4)	Starcloud's satellites will maneuver to maintain appropriate shell spacing and will operate within authorized altitudes and inclinations, consistent with applicable orbital tolerances.
A statement addressing the trackability of the space station(s), including whether the smallest dimension of the spacecraft is 10 cm or Space station(s) operating in LEO will be presumed trackable if each individual space station is 10 cm or larger in its smallest dimension, excluding deployable components. § 25.114(d)(14)(v)	Starcloud's satellites will exceed 10 cm in their smallest dimension and are therefore presumed trackable. They will autonomously estimate their position using GNSS and other sensors, and will regularly report this information to support rapid cataloging.
A statement describing how the operator plans to identify the space station(s) following deployment and whether space station tracking will be active or passive. Active tracking involves the use of instruments or devices that emit signals or radiation which are detected by sensors on the space station or other tracking systems. Passive tracking relies on detecting naturally occurring emissions or reflections off the surface of the space station or radio signals emitted by the station itself. Operators should also indicate if they plan to use enhanced tracking services and whether the information gathered by such services will be available to other operators. § 25.114(d)(14)(v)(A)	Following deployment, Starcloud will identify its satellites through third-party ground station networks. Starcloud certifies that each space station will include a unique telemetry marker that distinguishes it from other satellites or space objects. Before launch, Starcloud will assign each satellite a temporary nine-digit identifier, coordinates that identifier with USSPACECOM's 18th Space Defense Squadron, and will ensure it is published on Space-Track.org. Within several hours of deployment, Starcloud will upload propagated ephemerides and associated covariance data to Space-Track.org so USSPACECOM can use the

	information for identification and conjunction screening. Once USSPACECOM catalogs the satellites, Starcloud transitions to the assigned NORAD catalog identification numbers.
A statement indicating whether, prior to deployment, the space station(s) will be registered with the 18th Space Control Squadron (http://www.space-track.org/) or successor entity. § 25.114(d)(14)(v)(B)	Prior to deployment, Starcloud will register its satellites with the 18th Space Defense Squadron or a successor entity.
A statement describing 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. § 25.114(d)(14)(v)(C)	Starcloud will provide contact information to all registered satellite owner and operators on Space-Track.org to support both routine coordination and urgent coordination on a continuous 24/7 basis. Starcloud will share propagated ephemerides and covariance, including planned maneuvers, with the 18th Space Defense Squadron, other relevant entities, and satellite owner and operators through Space-Track.org. In addition, Starcloud will post these ephemerides on Space-Track.org.
Satellite Operations and Collision Risk	
For non-geostationary satellites, a statement identifying the characteristics of the space station(s)' orbits that may present a collision risk, including any planned and/or operational space stations in those orbits. This statement must 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. § 25.114(d)(14)(iv)(A)(2). If the space station operator is relying on coordination with another system, the statement must indicate what steps have been taken to contact and ascertain the likelihood of successful coordination of physical operations with the other system. § 25.114(d)(14)(iii)	Starcloud will make all reasonable attempts to coordinate with other users of the orbits specified in this application. Where coordination is not possible, Starcloud satellites will assume maneuver responsibility to mitigate conjunction risk when the probability exceeds internal conservative risk thresholds.
For geostationary satellites, 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. §	N/A

25.114(d)(14)(iii). If relevant, the statement must include the identities of those parties and the measures that will be taken to prevent collisions. § 25.114(d)(14)(iv)(B)	
A certification 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. § 25.114(d)(14)(iv)(A)(5)	Starcloud certifies that, upon receipt of a space situational awareness conjunction warning, it will review the alert and take all feasible steps to assess collision risk and, if necessary, mitigate that risk. As appropriate, these steps may include contacting the operator of any active spacecraft involved, sharing ephemeris and other relevant operational information, and adjusting space station attitude and or operations. In the unlikely event that a Starcloud satellite cannot mitigate a conjunction risk, Starcloud will make every effort to coordinate with the owner or operator of the other object.
Collisions with Large Objects	
A statement that the space station operator has assessed and limited the probability of the space station becoming a source of debris by collisions with large debris or other operational space stations. § 25.114(d)(14)(iii), § 25.114(d)(14)(iv)	Starcloud will assess and reduced the likelihood that its system could become a source of debris, including from collisions with large debris or other operational space stations.
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).	Starcloud will assess and limit the probability of collision between its satellites and other large objects to ensure it remains below 0.001 during all mission phases.
The collision risk may be assumed zero for a space station during the period of time when the satellite or space station is able to effectively conduct avoidance maneuvers. As a guideline, effective avoidance maneuvers reduce the probability of collision (Pc) by at least 1.5 orders of magnitude from the mitigation threshold (recommended to be 1E-4) while not creating any additional conjunctions with a Pc value above the mitigation threshold.	Starcloud confirms that it will conduct collision avoidance procedures throughout the mission, including conjunction assessment, avoidance maneuver execution, trajectory planning, conjunction assessment for any planned trajectory change, and notification to potentially affected operators of any planned trajectory change. Starcloud will perform conjunction screening and, as needed, avoidance maneuvers across all operational phases, including prior to passive disposal.

	Starcloud will use a collision avoidance maneuver trigger which is significantly more conservative than common industry practice and the thresholds discussed in NASA's Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook. Each satellite will carry sufficient propellant and have the required maneuvering capability to execute avoidance maneuvers throughout its lifecycle, from deployment through disposal. For active satellites, collision risk may be assumed to be effectively negligible because Starcloud's collision avoidance system mitigates any conjunction with collision probability above 1e-5, with a mitigation target of 1e-6 or lower.
If there is a planned tether deployment, an assessment of large object collision risk with the tether deployment, the impact on deorbit time, and a statement as to whether the tether can be retracted.	Starcloud's satellite system will not deploy tethers.
Collisions with Small Objects	
A statement that the operator has assessed and limited the probability of the space station becoming a source of debris by collisions with small debris or meteoroids that could cause loss of control that would prevent post mission disposal. A statement about whether this probability for an individual space station is 0.01 (1 in 100) or less, as calculated using the NASA DAS or a higher fidelity assessment tool. § 25.114(d)(14)(i), § 25.114(d)(14)(ii)	Starcloud will make every effort to minimize the probability that its satellites will become a source of debris by collisions with small debris or meteoroids. Satellites in the system will exhibit a probability below 0.01 for the requested orbits in this Application as calculated using the NASA DAS or a higher fidelity tool.
Proximity Operations	
Satellites conduct proximity operations when they are intentionally located or maneuvering near another spacecraft or other large objects in space. 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	Satellites in this Starcloud system will not conduct proximity operations. For any systems in the future which require proximity operations separate authorization will be sought.

measures taken to mitigate those risks. § 25.114(d)(14)(vi)	
Debris Released and Intentional Breakup	
A statement that the space station operator has assessed and limited the amount of debris released in a planned manner during normal operation. § 25.114(d)(14)(i)	No debris will be released during normal operations.
Where applicable, this statement must include an orbital debris mitigation disclosure for any separate deployment devices (such as rings or other deployment vehicles, sometimes referred to as "freeflyers," but not including launch vehicles) used to deploy the spacecraft. § 25.114(d)(14)(i)	Starcloud's system will not use any separate deployment devices.
Explosion Risk and End of Life Passivation	
A statement that the operator has assessed and limited the probability of accidental explosions during and after the completion of mission operations. § 25.114(d)(14)(ii), § 25.114(d)(14)(iii)	Starcloud's system inherently poses no significant risks of any significant accidental explosions. The system propellant tanks are low pressure / low stored energy, and on-board batteries are minimal. During the mission, the small batteries will be instrumented with fault detection, isolation, and recovery to continually monitor and preclude conditions that could result in the remote possibility of energetic discharge and subsequent generation of debris.
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. § 25.114(d)(14)(ii), § 25.114(d)(14)(iii). The Space Bureau generally will consider as sufficient a statement that the operator has assessed and limited the probability of accidental explosions during mission operations by means of a failure mode verification analysis or similar process.	Starcloud has assessed and limited the probability of accidental explosions during mission operations by means of failure mode analysis.
This statement 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	Starcloud will remove all stored energy when the satellites reach their disposal orbit.

stored energy, or through other equivalent procedures specifically disclosed in the application. § 25.114(d)(14)(ii), § 25.114(d)(14)(iii)	
A statement about whether the spacecraft will contain any liquids that if released either intentionally or unintentionally will persist in droplet form. In particular, the operator should identify any ionic liquids. If the operator identifies any such liquids that would not evaporate or sublimate if released, the statement should also address the length of time such liquid would remain in orbit, any natural processes that would result in dispersion of the droplets, how effectively the liquid is contained, and whether the propulsion system is shielded from micrometeoroid and debris strikes that may result in leakage are all relevant considerations and the type of information that could be included as part of this disclosure. § 25.114(d)(14)(iii)	Starcloud's satellites will contain liquids that if released will persist in droplet form.
Post-Mission Disposal	
A statement detailing the disposal plans for the space station, including the quantity of fuel, if any, that will be reserved for disposal maneuvers. § 25.114(d)(14)(iv), § 25.114(d)(14)(vii)	Starcloud's satellites will retain enough propellant to lower orbit for atmospheric reentry while conducting collision avoidance maneuvers during transit.
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. § 25.114(d)(14)(vii)(A)	N/A
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. § 25.114(d)(14)(vii)(B). Please note whether re-entry of the spacecraft will be completed as soon as practicable, but no later than five years	Starcloud plans to use uncontrolled atmospheric reentry for active end-of-life disposal immediately at the end of the satellite's life. (controlled reentry will be attempted but not relied upon). The spacecraft necessarily have a large surface area for their size. For this reason, in the case of a satellite failure, in the worst case 850 km orbit, the satellite will passively decay in 16.2 years per Starcloud's analysis. This situation is a backup contingency only in the event of propulsion failure, not the primary means of compliance.

following completion of the mission. § 25.114(d)(14)(vii)(D)(1).	
For non-GSO satellites and satellites NOT terminating operations in an orbit in or passing through the low-Earth orbit region below 2,000 km altitude, the statement must indicate whether disposal will involve use of a storage orbit or long-term atmospheric reentry and rationale for the selected disposal plan. § 25.114(d)(14)(vii)(C).	N/A
For non-GSO satellites, a statement demonstrating 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. § 25.114(d)(14)(vii)(D)(1).	Starcloud confirms that the probability of success for its planned disposal method, atmospheric re-entry, is at least 0.99 for each individual space station. Starcloud's design and operations target a probability of successful disposal of >0.999 per space station, supported by redundant maneuvering capability, fault-tolerant TT&C, onboard autonomy, and propellant reserves sufficient to execute disposal under all credible single-failure scenarios.
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 ISS, 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. § 25.114(d)(14)(iv)(A)(3)	Starcloud will coordinate with NASA and the Chinese Space Agency to ensure safe transit of the orbits of occupied space stations. Starcloud currently coordinating with NASA in this manner for its Starcloud-1 satellite (File Number 1019-EX-CN-2024).
A disclosure indicating whether the atmospheric re-entry will be an uncontrolled re-entry or a controlled targeted re-entry. § 25.114(d)(14)(vii)(D)(2)(i)	Starcloud will attempt a controlled re-entry where practically feasible but will not rely on this disposal method. If controlled re-entry is not feasible, the satellite will reenter in an uncontrolled manner.
Atmospheric Re-Entry Hazard	
If planned disposal is by atmospheric reentry, the statement must also include: 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 that the	Starcloud ensures by design that no surviving components reach the Earth's surface with kinetic energy greater than 15 joules and casualty risk <1e-4.

calculated casualty risk for an individual spacecraft using the NASA DAS or a higher fidelity assessment tool is less than 0.0001 (1 in 10,000). § 25.114(d)(14)(vii)(D)(2)(ii). If the estimated human casualty risk is not zero, applicants should address whether design-for-demise approaches as well as other measures like targeted re-entry away from landmasses to further reduce re-entry human casualty risk were considered.	

Overview

1. No orbital debris to be released as part of normal operations

2. No credible scenarios for spacecraft breakup

3. Collision probability is compliant with NASA's ODAR requirement 4.5-1 and 4.5-2 as calculated by DAS v3.2.6

4. At end-of-life Starcloud's satellites will actively deorbit satisfying the FCC's 5-year requirement. In the event of a failed satellite, orbit decay lifetime due to atmospheric drag is less than 25 years and therefore compliant with ODAR requirement 4.6

5. Reentry debris casualty risk is compliant with NASA ODAR 4.7-1 as calculated by DAS v3.2.6

Launch, Deployment, Operations and Decommissioning

The launch and deployment profile consists of launch and insertion into an lower orbit altitude which results in rapid reentry if the satellite fails, followed by spacecraft commissioning then orbit raising maneuvers from the insertion orbit to the operational orbit for primary payload operations.

After insertion into the primary operational orbit, this orbit will be actively maintained using the attitude control system and the propulsion system. At end of life the satellite will perform a series of deorbit burns to safely lower the spacecraft's altitude until re-entry is achieved.

A failure of the bus resulting in loss of control at any point in the flight profile will still result in compliance with Requirement 4.6-1(a) as a worst-case deorbit time scenario for a failure at the maximum altitude of 850 km.

Spacecraft maneuver capability, including attitude and orbit control and time period during which capabilities will be exercised:

The spacecraft is equipped an attitude control system to provide attitude stability in three axes and a set of redundant propulsion systems. Attitude and orbit control will be exercised during the entire mission duration, from insertion to operational orbits and maintenance at these operational orbits. The attitude and orbit control will be exercised for the orbital transfer and operational orbit station-keeping and collision avoidance.

Reason for selection of operational orbit(s) (such as ground track, SSO, GEO sync, instrument resolution, or co-locate with other spacecraft):

The specified orbits are required to maximize solar illumination and accessibility from planned launch sites and vehicles, while minimizing the radiation environment and aerodynamic drag.

Identification of any interaction or potential physical interference with other operational spacecraft:

No physical interaction is expected with other objects in orbit, and collision avoidance maneuvers will be executed to eliminate the risk of this.

Identification, including type, mass and pressure, of all fluids (liquids and gasses) planned to be on board, excluding fluids in sealed heat pipes. Description of all fluid systems, including size, type, and qualifications of fluid containers such as propellant and pressurization tanks, including pressurized batteries:

No fluid in pressurized batteries. The thermal management and propulsions systems contains a volume of liquid at < 2 atmospheres of pressure which is circulated via several pumps, without significant stored chemical energy.

Description of any range safety or other pyrotechnic devices:

None. Space vehicle separation will be accomplished using non-explosive mechanisms. Solar array deployment will also be achieved using mechanisms that do not release any debris.

Description of the electrical generation and storage system:

The spacecraft uses a set of small battery assemblies for powering critical bus systems during rare eclipses. These will be charged at the time of integration, and two deployable solar arrays will recharge the assembly on-orbit. Power management and distribution electronics onboard the spacecraft control the charge of the battery and flow of power to other spacecraft elements. The large majority of the spacecraft's power is delivered directly from the solar arrays to voltage regulators then directly to the payload without interacting with the battery system. The battery system is only connected to low power subsystems on the spacecraft, not the primary computing payload.

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

None

Identification of any radioactive material on board:

None

Address the trackability of the spacecraft. Spacecraft operating in low-Earth orbit will be presumed trackable if each individual spacecraft is 10 cm or larger in its smallest dimension, excluding deployable components:

The spacecraft is in low-Earth orbit and has a smallest dimension measuring more than 10 cm. Thus, it is trackable.

Description of any planned proximity operations or docking with other spacecraft in LEO or GEO, including the controls that will be used to mitigate the risk of a collision that could generate debris or prevent planned later passivation or disposal activities for either spacecraft:

Starcloud satellites are not planned to operate in close proximity to other spacecraft.

Identification of any object > 1mm expected to be released from spacecraft after launch:

None

Rationale/necessity for release of each object:

N/A

Time of release of each object, relative to launch time:

N/A

Release velocity of each object with respect to spacecraft:

N/A

Expected orbital parameters of each object after release:

N/A

Calculated orbital lifetime of each object, including time spent in Low Earth Orbit:

N/A

Assessment of spacecraft compliance with ODAR Requirements 4.3-1 and 4.3-2:

- 4.3-1, Mission Related Debris Passing Through LEO: COMPLIANT
- 4.3-2, Mission Related Debris Passing Through GEO: COMPLIANT

Potential causes of spacecraft breakup during deployment and mission operations:

There are no credible causes of spacecraft breakup during nominal deployment and mission operations.

Summary of failure modes and effects analyses of all credible failure modes that may lead to an accidental explosion:

The spacecraft uses water based propellant with no stored chemical energy. The battery safety systems are discussed in the assessment of spacecraft compliance with ODAR requirement 4.4-1 and describes combined faults required for the mutually exclusive failures that lead to battery venting. The batteries are equipped with a safety vent feature that vents excessive pressure build-up, precluding explosions.

Detailed plan for any designed spacecraft breakup:

None

List of components which are passivated at End of Mission (EOM). List includes method of passivation and amount which cannot be passivated:

The following components will be passivated at EOM:

- Solar panels - Method of passivation: disconnected from the electrical power system (EPS) at EOM using an electronic switch.
- Batteries - Method of passivation: will be passivated at EOM.

Items which are required to be passivated, but cannot be due to their design:

None

Assessment of spacecraft compliance with ODAR requirements 4.4-1 - 4.4-4:

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

- **Required Probability:** 0.001 – **COMPLIANT;** expected probability of <0.001

Battery explosion:

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

Probability: Extremely Low. It is believed to be less than 0.01% given that multiple independent (not common mode) faults must occur for each failure mode to cause the ultimate effect (explosion). Each battery cell is UL/UN certified with individual over-voltage and over-current protection.

Supporting Rationale:

- **Failure Mode 1:** Internal cell short circuit
    - **Mitigation 1:** Protoflight level sine burst, sine and random vibration in three axes of the spacecraft, thermal cycling of the spacecraft, and extensive functional testing followed by maximum system rate-limited charge and discharge cycles will be performed to prove that no internal short circuit sensitivity exists. Additional environmental and functional testing of the batteries at the power subsystem vendor facilities will also be conducted on the batteries at the component level.

    - **Combined faults required for realized failure:** Environmental testing AND functional charge/discharge tests must both be ineffective in discovery of the failure mode.
- **Failure Mode 2:** Internal thermal rise due to high load discharge rate.
    - **Mitigation 2:** Battery cells will be tested in the lab for high load discharge rates in a variety of flight-like configurations to determine the feasibility of an out-of-control thermal rise in the cell. Cells will also be tested in a hot environment (5 cycles at 50°C, then to -20°C) in order to test the upper limit of the cells' capability.
    - **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 3:** This failure mode is negated by:
        - Qualification will test short circuit protection on each external circuit,
        - Design of battery packs and insulators such that no contact with nearby board traces is possible without being caused by some other mechanical failure,
        - Observation of such other mechanical failures by protoflight level environmental tests (sine burst, random vibration, thermal cycling).

    - **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 4:** 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 OR the satellite integrator fails to install proper venting.
- **Failure Mode 5:** Crushing
    - **Mitigation 5:** Failure mode prevented by design. No moving parts near the battery assembly.
    - **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 6:** These modes are negated by:
        - Battery holder/case design made of non-conductive plastic,
        - Operation in vacuum such that no moisture can affect insulators.
    - **Combined faults required for realized failure:** Abrasion or piercing of circuit board coating or battery wire harness insulator AND dislocation of battery packs AND failure of battery terminal insulators

AND failure to detect such failures in environmental tests must occur to result in this failure mode.

- **Failure Mode 7:** Excess battery cell temperature due to orbital environment and high discharge combined.
  - **Mitigation 7:** The spacecraft thermal design will negate this possibility. Thermal rise has been analyzed in combination with space environment temperatures showing that batteries do not exceed normal allowable operating temperatures under a variety of modeled cases, including worst-case orbital scenarios. Analysis shows these temperatures to be well below temperatures of concern for explosions.
  - **Combined faults required for realized failure:** incorrect thermal analysis AND thermal design AND mission simulations in thermal chamber testing AND over-current monitoring and control must all fail for this failure mode to occur.

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

Compliance Statement: The spacecraft includes the ability to fully disconnect the Lithium Ion cells from the charging current of the solar arrays. Once the satellite reaches its End of Life (EOL), this feature will be used to completely passivate the batteries by removing all energy from them. In the unlikely event that a battery cell does explosively rupture, the small size, mass, and potential energy, of these small batteries is such that while the spacecraft could be expected to vent gases, the debris from the battery rupture should be contained within the spacecraft due to the lack of penetration energy to the multiple enclosures surrounding the batteries.

4.4-3: Limiting the long-term risk to other space systems from planned breakups:

Compliance Statement: Requirement not applicable, no planned breakups

4.4-4: Limiting the short-term risk to other space systems from planned breakups:

Compliance Statement: Requirement not applicable, no planned breakups

Calculation of spacecraft probability of collision with space objects larger than 10 cm in diameter during orbital lifetime of spacecraft:

Starcloud will assess and limit the probability of collision between its satellites and other large objects to ensure it remains below 0.001 during all mission phases.

Detailed description and assessment of efficacy of any planned debris avoidance capability intended to help in meeting requirement 4.5-1:

Starcloud satellite is equipped with a three-axis control system and redundant propulsion systems. These attitude and orbit control systems are used in tandem with situational awareness, conjunction assessment, and collision avoidance (COLA) ground operations software to maneuver the vehicle out of any potential collisions, thus reducing the collision risk to effectively zero. Starcloud satellite will provide the required amount of propellant to enable collision avoidance given the estimated number of potential conjunction events in its operational orbit.

If at any time during the spacecraft's mission or de-orbit phase the spacecraft will operate in or transit through the orbits used by any planned or inhabitable spacecraft, including the International Space Station, describe the design and operational strategies, such as coordination, that will be used to minimize the risk of collision and avoid posing any operational constraints to the spacecraft:

Starcloud will coordinate with NASA and the Chinese Space Agency to ensure safe transit of the orbits of occupied space stations. Starcloud currently coordinating with NASA in this manner for its Starcloud-1 satellite (File Number 1019-EX-CN-2024).

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:

Upon receipt of a space situational awareness conjunction warning, the operator will attempt to contact the operator of any active spacecraft involved in such a warning, share ephemeris data and other appropriate operational information with any such operator, and modify the spacecraft's attitude, orbit, and/or operations to avoid a collision. If the operator of the other spacecraft does not have maneuvering capabilities or is not expedient in response, the operator for Starcloud satellite will upload potential maneuvers to the 18th Space Defense Squadron to avoid a collision. High-risk events will be mitigated to at least one and a half orders of magnitude below the collision probability mitigated action threshold of 1E-5. Starcloud will assume maneuver responsibility when coordination can't be achieved above internal thresholds.

Description of spacecraft disposal option selected:

Per NASA-STD 8719.4, Starcloud satellite will be actively disposed of via atmospheric reentry. In the unlikely case that multiple satellite systems fail causing the satellite to be uncontactable, the operational altitude leads to natural forces that will lead to atmospheric reentry once the operations, including station-keeping with maneuvers, are ceased.

Calculation of area-to-mass ratio after post-mission disposal:

The final area-to-mass ratio is calculated using the dry mass of the vehicle and the average cross-sectional area. Average cross-sectional area is calculated using the equation for estimated average cross-sectional area for non-convex shapes from NASA-STD-8719.14C: A_avg = (A_max + A_1 + A_2)/2, where A_max is the maximum cross-sectional area and A_1 and A_2 are the cross-sectional areas for the two viewing directions orthogonal to the maximum cross-sectional area viewing direction. Using this method the spacecraft area-to-mass ratio is 0.221 m2/kg.

Calculation of area-to-mass ratio for worst-case deorbit scenario:

Additional analysis is provided for the worst-case deorbit scenarios in the following section on ODAR requirement 4.6-1, for deorbit time with the vehicle at the maximum altitude deployment. The average cross-sectional area for these two cases is calculated with the same result from NASA-STD-8719.14C as previously provided.

Assessment of spacecraft compliance with ODAR requirements 4.6-1 to 4.6-4:

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

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

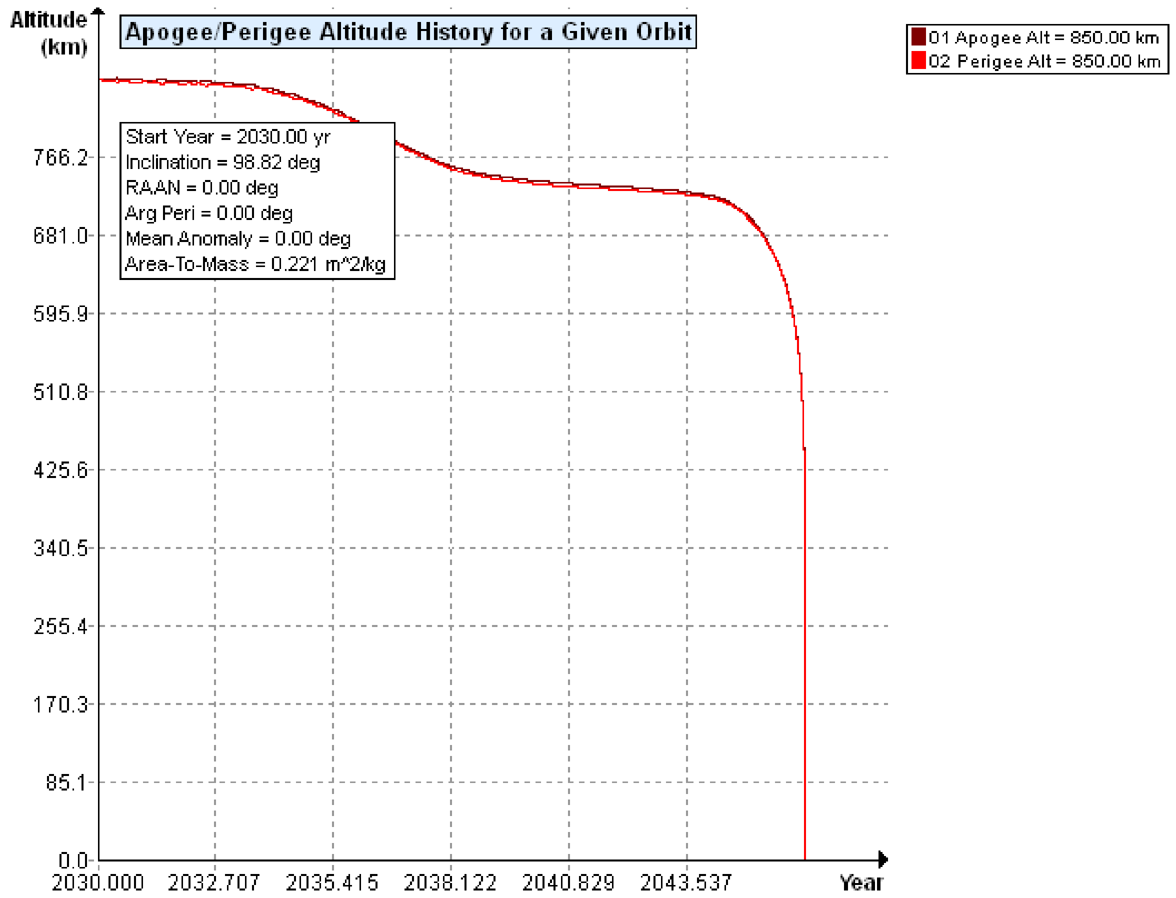
- Atmospheric reentry option: Leave the space structure in an orbit in which natural forces will lead to atmospheric reentry within 25 years after the completion of mission; or maneuver the space structure into a controlled de-orbit trajectory as soon as practical after completion of mission

- Direct reentry option: Maneuver the space structure into a controlled deorbit trajectory as soon as practical after completion of the mission.

- Storage orbit option: Maneuver the space structure into an orbit with perigee altitude above 2000km and ensure its apogee altitude will be below 19,700 km, both for a minimum of 100 years

- Direct retrieval: Retrieve the space structure and remove it from orbit within 10 years after completion of mission

Compliance Statement: The satellites will actively be maneuvered into a controlled deorbit trajectory as soon as practical after completion of the mission and is thus compliant with the FCC's 5 years rule. In the case of a critical satellite failure at worst case altitude, the DAS prediction for orbit lifetime following is approximately 16.2 years after completion of the mission. Accordingly, the spacecraft complies with NASA's 25-year re-entry requirement even in the case of satellite failure.



Apogee/Perigee history for the passive decay of a failed satellite.

4.6-2: Disposal for space structures near GEO: Not applicable

4.6-3: Disposal for space structures between LEO and GEO: Not applicable

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

The spacecraft will satisfy the requirement of deorbiting within 5 years per the FCC requirements after the end of the life of the satellite.

Summary of objects expected to survive uncontrolled reentry:

Starcloud satellites will be designed for demisability from the ground up. Starcloud will conduct full assessment of the satellite system with the latest available version of the DAS software to demonstrate so that no surviving components reach the Earth's surface with kinetic energy greater than 15 joules and casualty risk <1e-4.