Lumen Orbit

Lumen-1
Orbital Debris Assessment Report (ODAR)

V1.0

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Revision History

Revision	Date	Author(s)	Description
1.0	10/3/2024	Carlos Aizcorbe, Ezra Feilden	First release

I. Orbital Debris Assessment Report

This document contains the orbital debris assessment report (ODAR) for the Lumen Orbit, Inc. (“Lumen”) experimental spacecraft Lumen-1.
Table 1 includes a summary of the results in the following sections.

Table 1: Lumen-1 Compliance Information

ODAR Requirement	Compliant or N/A	Not Compliant
4.3.1-a	Compliant	
4.3.1-b	Compliant	
4.3.2	N/A	
4.4-1	Compliant	
4.4-2	Compliant	
4.4-3	N/A	
4.4-4	N/A	
4.5-1	Compliant	
4.5-2	Compliant	
4.6-1	Compliant	
4.6-2	N/A	
4.6-3	Compliant	
4.6-4	Compliant	
4.7-1	Compliant	
4.8-1	N/A	

II. Project Management & Mission Overview

Project Manager: Ezra Feilden
Foreign Government / Space Agency Participation: None
Schedule of Upcoming Mission Milestones: Launch scheduled for May - October 2025
Expected total mission duration: 1 year

The Lumen-1 mission is a demonstrator satellite mission in support of Lumen Orbit’s goal of building an in-orbit data center for earth observation satellites and other users. Lumen-1 is Lumen Orbit’s first satellite and will demonstrate a new type of satellite service. Following these demonstrations, Lumen-1 will passively deorbit within 6 months due to its VLEO operational orbit with no debris casualty risk.

The Lumen-1 experimental spacecraft will be launched on a SpaceX Falcon 9 rideshare and inserted into a 45 +/- 1.1 degree inclination orbit with a perigee and apogee of 515 km +/- 25 km. The Lumen-1 mission is comprised of four phases:

1. After release from the launch vehicle and post-launch bus commissioning, Lumen-1 will maneuver from its insertion orbit to its target operational 325 km circular orbit using its propulsion system. A more detailed discussion of the transfer orbit path is discussed in the ODAR. This segment is expected to take roughly 6 months.
2. When Lumen-1 reaches its operational orbit, it will commence testing of the primary payload - an on board computer. This segment is expected to take approximately 2 months.
3. Following completion of Lumen-1's primary mission, the spacecraft will monitor the mission's secondary payload - a commercial off-the-shelf software defined radio system (SDR). The effect of the space environment and radiation will be evaluated with periodic health checks in preparation for the future Lumen-2 mission.
4. Following competition of the mission objectives Lumen-1 will passively deorbit and fully demise.

<u>ODAR Summary:</u>
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 ODAR requirements 4.5-1 and 4.5-2 as calculated by DAS v3.2.8
4. Orbit decay lifetime due to atmospheric drag is less than 5 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

<u>Launch and Deployment Profile:</u>
The launch and deployment profile consists of launch and insertion into orbit, followed by the orbit lowering maneuvers from the insertion orbit to the operational orbit for primary and secondary payload operations. The Lumen-1 launch, insertion and deployment information is provided in Table 1.1.

Table 1.1: Summary of Lumen-1 Launch and Insertion, Operational Orbits Information

Launch Window Dates	31st May - 15th October 2025	
Launch Vehicle	SpaceX Falcon 9	
Lumen-1 Launch Configuration	Smallsat measuring 39 x 39 x 60 cm	
Mission Orbit	Target Launch Insertion	Primary Operational
Perigee altitude	515 km +/- 25 km	325 km +/- 10 km
Apogee altitude	515 km +/- 25 km	325 km +/- 10 km
Inclination	45° +/- 1.1°	45° +/- 1.1°
RAAN	TBC	TBC

<u>Launch and Insertion:</u>
The spacecraft, as scheduled, will launch on a SpaceX Falcon 9 rocket in 2025 on a rideshare mission. The launch and insertion orbit details are provided in Table 1.1.

<u>Approach:</u>
Following insertion, Lumen-1 will lower its apogee and perigee from the insertion orbit to the targeted primary operational circular orbit at 325 km altitude, 45-degree inclination. This will be achieved in two steps, illustrated in Figure 1 below:
1. Operating the thruster in the retrograde direction when the spacecraft is in the vicinity of its apogee, the perigee and apogee are lowered to 360 km and 490 km, respectively.
2. Operating the thruster in the retrograde direction when the spacecraft is in the vicinity of its perigee, the perigee and apogee are lowered to 325 km and 325 km, respectively.

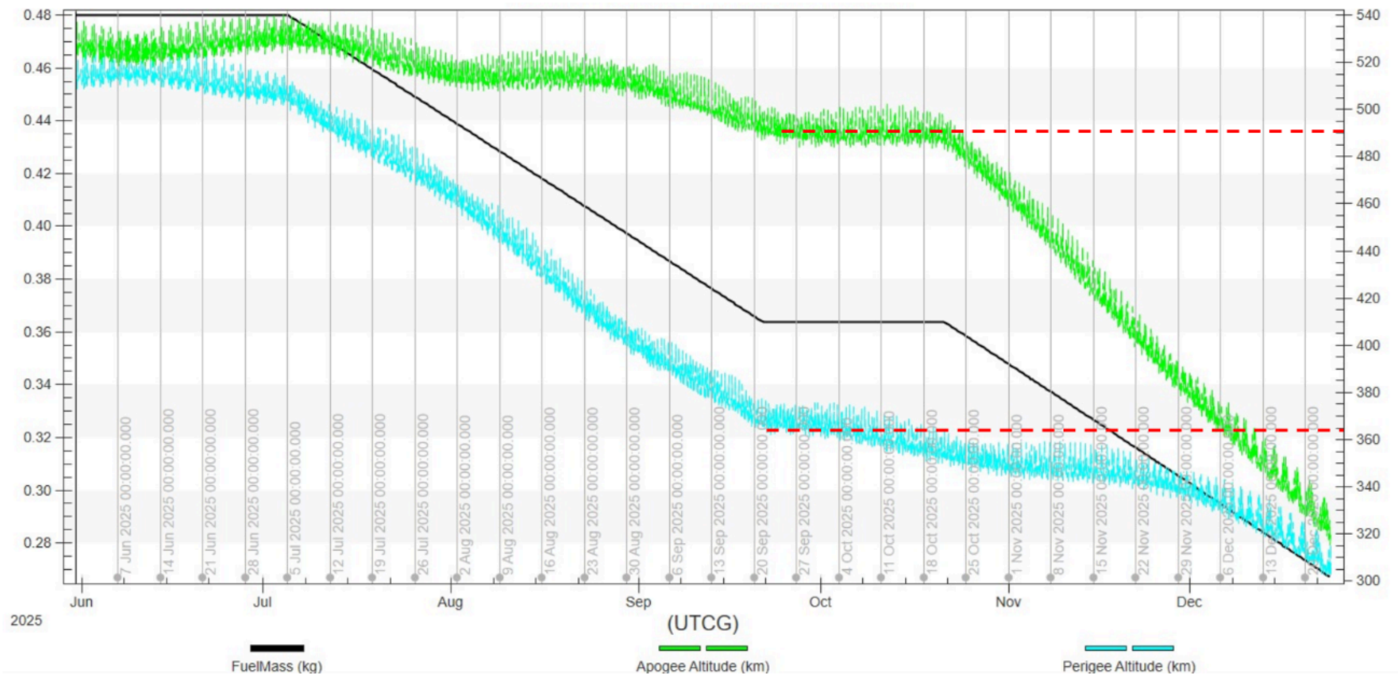

Figure 1: Orbit lowering maneuver from the launch insertion orbit to the primary operational orbit, simulated in Astrogator.

By lowering the perigee first, followed by the apogee, this maneuver takes advantage of the greatly increased aerodynamic drag at lower altitudes to assist in circularizing the orbit, thereby optimizing for propellant budget efficiency. Furthermore, the power budget does not allow for continuous operation of the thruster, therefore this maneuver is also the fastest route to the payload operation orbit given the specifications of the spacecraft bus.

After insertion into the payload operation orbit, this orbit will be actively maintained using the attitude control system and the propulsion system. Following payload operations in the primary operational orbit, the spacecraft will stop using the propulsion system to maintain its 325 +/-10km circular orbit to passively deorbit.

During the orbit-lowering maneuvers, where the spacecraft maneuvers from the insertion orbit to the primary operational orbit, it is possible that the spacecraft will transit through orbits used by planned or inhabited spacecraft, including the International Space Station ("ISS"). With respect to the operational strategies to minimize risk to the ISS or any other inhabitable spacecraft in low Earth orbit, Lumen Orbit intends to monitor the location of its satellites and work closely with organizations, such as the 18th Space Defense Squadron. Lumen Orbit also commits to discussing and coordinating this strategy directly with NASA and the ISS team.

Spacecraft maneuver capability, including attitude and orbit control and time period during which capabilities will be exercised: The spacecraft is equipped with a three-axis active control system and two gridded ion electric 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 325 km mid-inclination primary operational orbit is required to minimize the TID and flux of ionizing radiation, in order to protect electronic components in the payload which are sensitive to radiation.

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.

III. Spacecraft Description

Clear overall spacecraft dimensions: The physical dimensions of the Lumen-1 spacecraft bus are 39 cm x 39 cm x 60 cm, with solar panels stowed as shown in Figure 2.

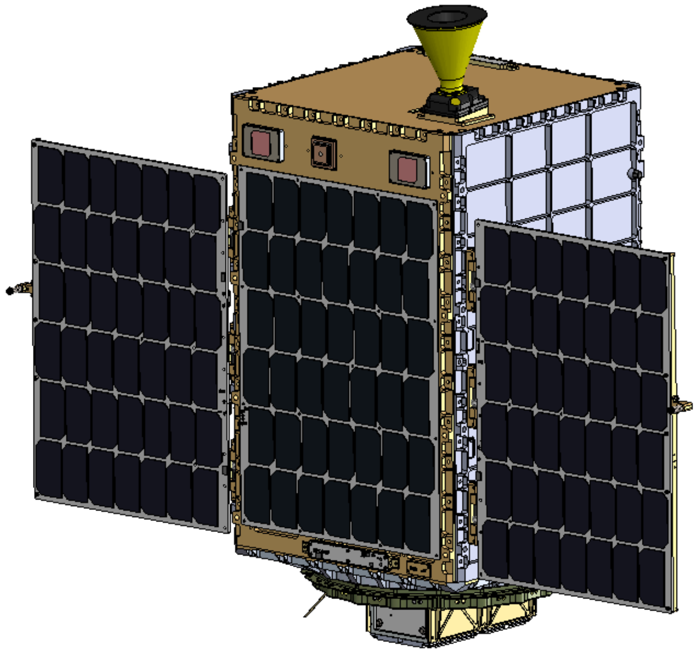

Figure 2: Lumen spacecraft

Total spacecraft mass at launch, including all propellants and fluids: ~49.74 kg

Dry mass of spacecraft at launch, minus consumables and propellants: ~49.34 kg

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 iodine ingots in the two ThrustMe propulsion systems are launched as a solid and only vaporized once on-orbit. The unit is delivered from the manufacturer already loaded with propellant. The internal payload module contains paraffin wax for thermal management purposes in a gelled state in a hermetically sealed container inside the spacecraft.

Description of all propulsion systems (e.g., cold gas, monopropellant, bi-propellant, solid propellant, electric, nuclear):
Propulsion system includes two ThrustMe NPT30-I2 modules. The NPT30-I2 is a gridded ion thruster with 0.48 kg of solid iodine propellant mass, a total impulse of 5.5kNs, and a nominal thrust of 1.1 mN. There are more than 26 NPT30-I2 thrusters in orbit as of 2024. The propellant for this system is iodine, which is stored as a solid, unpressurized. The iodine propellant is solid at room temperature and remains in solid state when contained in the unpowered NPT30-I2 thruster system. The thruster does not release any persistent liquids. The only way for the iodine to escape from the thruster is for the heater to evaporate the ingot. The path from the tank to space requires the iodine to pass through small holes in the grid system.

Description of all active and/or passive attitude control systems with an indication of the normal attitude of the spacecraft with respect to the velocity vector:
Attitude determination and control system includes three reaction wheels, a reaction wheel controller, three magnetorquer rods, torque rod drivers, an ADCS controller, one star tracker, three 3-axis magnetometers, two GPS antennas, a GPS receiver, a 3-axis inertial measurement unit, and coarse sun sensors. Nominally, when not pointing an antenna or operating the propulsion system, the spacecraft will fly with its solar panels in a sun-pointing configuration.

Description of any range safety or other pyrotechnic devices: None.
Space vehicle separation will be accomplished using the MKII Lightband debris-free low-shock release system. 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 2 set of 4x Lithium Ion Samsung 50E 21700 5000mAh 9.8A cells, two sets of 7x Lithium Ion Samsung 40T 21700 4000mAh 45A cells, and one set of 7x Lithium Ion Molicel P45B 21700 4500mAh 45A cells giving a total of 29 cells. The battery assemblies will be charged at the time of integration, and two deployable solar arrays and one fixed solar array 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.

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.

How the operator plans to identify the spacecraft following deployment and whether spacecraft tracking will be active or passive:
Spacecraft tracking will be both active and passive. Prior to deployment, an initial ephemeris is produced by the launch service that will be used to schedule a contact time window with the ground station. The accuracy of the ephemeris will depend on the launch vehicle's performance, delays, and deployment times. A more accurate ephemeris will be made available shortly after deployment. After deployment, when the satellite asserts complete control using the ADCS, the Lumen-1 satellite engages its GPS unit, collects positional states, and establishes contact with the nearest available Lumen-contracted ground station. The collected data will be used to identify the spacecraft from TLE once they become available from the 18th Space Control Squadron.

Whether, prior to deployment, the spacecraft will be registered with the 18th Space Control Squadron or successor entity:
Prior to deployment, the spacecraft will be registered with the 18th Space Control Squadron via their Satellite Registration Form and Space Situational Awareness (SSA) Sharing Agreement.

The extent to which the spacecraft 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:
Lumen Orbit intends to provide the 18th Space Control Squadron with information regarding initial deployment, owner/operator (O/O) ephemeris, and planned maneuvers. This is intended to provide better space situational awareness and improve the accuracy of conjunction analysis (CA). The higher accuracy O/O ephemeris will improve the quality of the CA and reduce the frequency of Conjunction Data Messages (CDMs). Lumen Orbit intends to share ephemeris with other operators on an as-needed basis.

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:
Lumen-1 is not planned to operate in close proximity to other spacecraft.

IV. Assessment of spacecraft debris released during normal operations

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 (per DAS):
- 4.3-1, Mission Related Debris Passing Through LEO: COMPLIANT
- 4.3-2, Mission Related Debris Passing Through GEO: COMPLIANT

V. Assessment of spacecraft intentional breakups and potential for explosion

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 has no pressurized vessels and no chemical propellants with stored chemical energy. The battery safety systems are discussed in the assessment of spacecraft compliance with ODAR requirement 4.4-1 and describe 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.
- **Reaction wheels** - Method of passivation: will be switched off and power removed 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 0.000

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

VI. Assessment of spacecraft potential for on-orbit collisions

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

Per DAS, the probability of collision with large space objects is 3.8843E-06

Assessment of spacecraft compliance with ODAR requirements 4.5-1 and 4.5-2:

- **4.5-1: Limiting debris generated by collisions with large objects when operating in Earth Orbit (per DAS):**
  - **COMPLIANT:** Collision Probability < 0.001
- **4.5-2: Limiting debris generated by collisions with small objects when operating in Earth or Lunar Orbit:**
  - **COMPLIANT:** Not applicable as the planned disposal method is via atmospheric reentry that does not require a specific orientation or drag state.

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

Lumen-1 is equipped with a three-axis active control system and an electric propulsion system. 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. Lumen-1 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:

During the orbit-lowering maneuvers, where the spacecraft maneuvers from the insertion orbit to the primary operational orbit, it is possible that the spacecraft will transit through orbits used by planned or inhabited spacecraft, including the ISS. With respect to the operational strategies to minimize risk to the ISS or any other inhabitable spacecraft in low Earth orbit, Lumen Orbit intends to monitor the location of its satellites and work closely with organizations, such as the 18th Space Defense Squadron. Lumen Orbit also commits to discussing and coordinating this strategy directly with NASA and the ISS team. More generally, Lumen Orbit will work with the Space Data Association to coordinate physical operation of its constellation with other operators.

Lumen Orbit will be able to conduct collision avoidance maneuvers using differential drag techniques with sufficient advance notice. For the provided cases, the spacecraft is equipped with attitude control and propulsion systems, and the operations center for the spacecraft has collision avoidance operationally active, thus the collision risk during these operations is effectively zero. Propellant margin is reserved throughout the mission for potential collision avoidance maneuvers, and the spacecraft is collision avoidance capable until the demise altitude, well below the orbit of the ISS.

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 Lumen-1 will upload potential maneuvers via API to the 18th Space Control 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.

ODAR SECTION 6: ASSESSMENT OF SPACECRAFT POST-MISSION DISPOSAL PLANS AND PROCEDURES

Description of spacecraft disposal option selected:

Per NASA-STD 8719.4, Lumen-1 will be disposed of via atmospheric reentry. The operational altitude leads to natural forces that will quickly lead to atmospheric reentry once the operations, including station-keeping with maneuvers, are ceased.

Identification of all systems or components required to accomplish any post-mission disposal maneuvers. Plan for any spacecraft maneuvers required to accomplish post-mission disposal:

No systems, components, special maneuvers, or operations are required for post-mission disposal. The spacecraft orbit will passively decay until atmospheric reentry.

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.

Final area-to-mass ratio calculation:

- **Spacecraft mass:** 49.33kg (dry mass)
- **Cross-sectional area:** 0.42839 m^2 (average)
- **Area-to-mass ratio:** 0.00868 m^2/kg (final)

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 launch deployment. The average cross-sectional area for these two cases is calculated using the same equation from NASA-STD-8719.14C as previously provided.

Area-to-mass ratio calculation:

- **Spacecraft mass:** 49.73 kg (wet mass)
- **Cross-sectional area:** 0.42839 m² (average)
- **Area-to-mass ratio:** 0.00862 m²/kg (final)

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

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

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

Compliance Statement: The DAS prediction for orbit lifetime following a nominal one-year mission lifetime is approximately 2 months after completion of the mission, assuming a worst-case operating altitude of EOM of 335 km, as shown in Figure 6.1. Accordingly, the spacecraft complies with the FCC 5-year re-entry requirement.

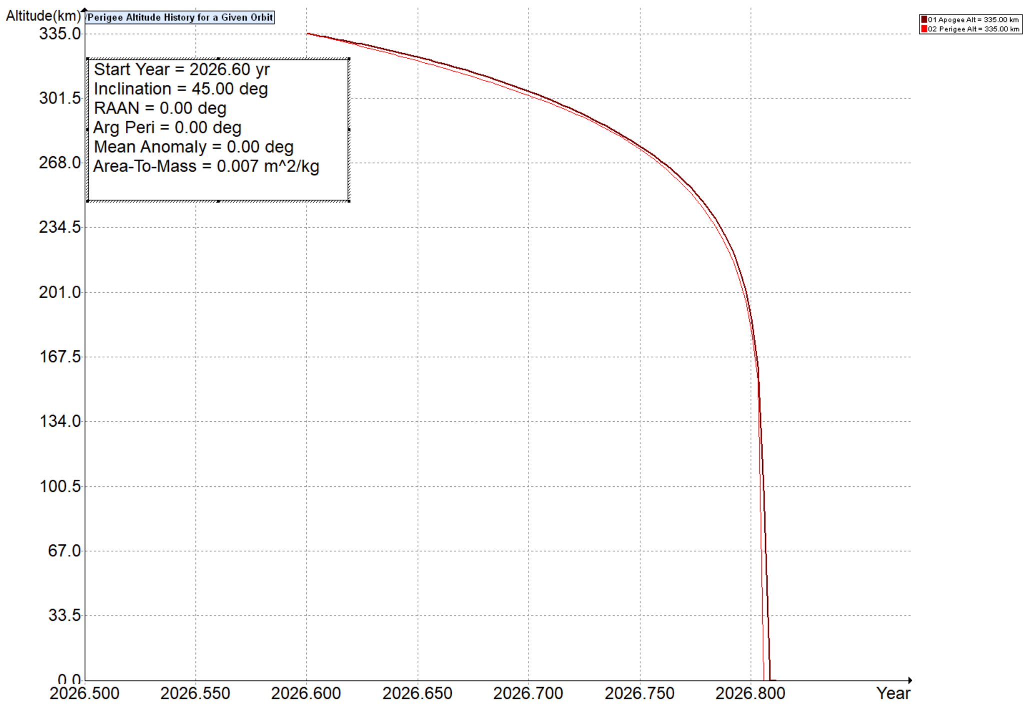

Figure 6.1 Apogee/Perigee history for a 335km orbit

If the spacecraft were deployed at the worst-case altitude of 540 km and fails, the satellite would re-enter the Earth's atmosphere in approximately 9.835 years. This is shown in Figure 6.2.

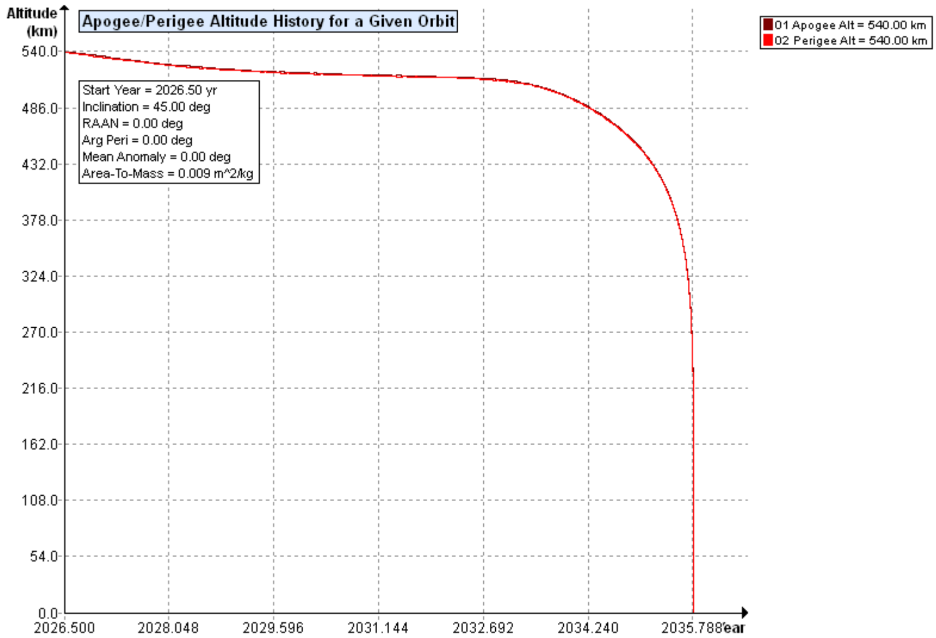

Figure 6.2 Apogee/Perigee history for a 540km orbit

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 after deployment as discussed in Section 6.4.1 Reliability of passive deorbit has been validated through different missions in which the accuracy of the orbit's dwell time has a small variation of a couple of months.

VII. Assessment of spacecraft reentry hazards

Summary of objects expected to survive uncontrolled reentry: No spacecraft components are expected to survive uncontrolled reentry per DAS.

Assessment of spacecraft compliance with ODAR requirement 4.7-1:

- 4.7-1(a): Limit the risk of human casualty from surviving debris for an uncontrolled reentry to no greater than 1 in 10,000: COMPLIANT
- 4.7-1(b): Not applicable, only for controlled reentry
- 4.7-1(c): Not applicable, only for controlled reentry

VIII. Assessment for special classes of space missions

None of the special classes in this Section are applicable.

IV. DAS v3.2.8 Output File

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

07 26 2024; 17:12:53PM Processing Requirement 4.3-2: Return Status: Passed

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

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

07 26 2024; 17:16:49PM Processing Requirement 4.5-1: Return Status: Passed

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

INPUT

Space Structure Name = Lumen-1
Space Structure Type = Payload
Perigee Altitude = 515.000 (km)
Apogee Altitude = 515.000 (km)
Inclination = 45.000 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0071 (m^2/kg)
Start Year = 2025.450 (yr)
Initial Mass = 49.740 (kg)
Final Mass = 49.740 (kg)
Duration = 5.000 (yr)
Station-Kept = False
Abandoned = True
Long-Term Reentry = False

OUTPUT

Collision Probability = 3.8843E-06
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

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

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

07 26 2024; 17:17:07PM Processing Requirement 4.6 Return Status: Passed

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

INPUT

Space Structure Name = Lumen-1
Space Structure Type = Payload

Perigee Altitude = 515.000000 (km)
Apogee Altitude = 515.000000 (km)
Inclination = 45.000000 (deg)
RAAN = 0.000000 (deg)

Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.007090 (m^2/kg)
Start Year = 2025.450000 (yr)
Initial Mass = 49.740000 (kg)
Final Mass = 49.740000 (kg)
Duration = 5.000000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 462.685268 (km)
PMD Apogee Altitude = 464.002433 (km)
PMD Inclination = 44.992360 (deg)
PMD RAAN = 102.015223 (deg)
PMD Argument of Perigee = 345.662199 (deg)
PMD Mean Anomaly = 0.000000 (deg)
Long-Term Reentry = False

OUTPUT

Suggested Perigee Altitude = 462.685268 (km)
Suggested Apogee Altitude = 464.002433 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2034 (yr)
Requirement = 61
Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
07 26 2024; 17:17:17PM Project Data Saved To File
07 26 2024; 17:17:22PM Requirement 4.5-2: Compliant

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

07 26 2024; 17:18:24PM *********Processing Requirement 4.7-1
Return Status : Passed

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

name = Lumen-1
quantity = 1
parent = 0
materialID = 8
type = Box
Aero Mass = 49.740002
Thermal Mass = 49.740002
Diameter/Width = 0.400000
Length = 0.825000
Height = 0.400000

name = Structural Panel +X
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 2.680000

Thermal Mass = 2.680000
Diameter/Width = 0.370000
Length = 0.370000
Height = 0.030000

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

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

name = Structural Panel -Y
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.600000
Thermal Mass = 1.600000
Diameter/Width = 0.350000
Length = 0.490000
Height = 0.010000

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

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

Height = 0.010000

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

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

name = Star tracker
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.230000
Thermal Mass = 0.230000
Diameter/Width = 0.090000
Length = 0.110000
Height = 0.090000

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

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

name = DEP

quantity = 3
parent = 1
materialID = 8
type = Box
Aero Mass = 1.220000
Thermal Mass = 1.220000
Diameter/Width = 0.190000
Length = 0.420000
Height = 0.120000

name = Reaction wheel
quantity = 3
parent = 1
materialID = 8
type = Box
Aero Mass = 0.230000
Thermal Mass = 0.230000
Diameter/Width = 0.070000
Length = 0.080000
Height = 0.040000

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

name = Torque Rod
quantity = 3
parent = 1
materialID = 19
type = Box
Aero Mass = 0.048600
Thermal Mass = 0.048600
Diameter/Width = 0.030000
Length = 0.050000
Height = 0.020000

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

name = Solar Panel Hinge
quantity = 6
parent = 1
materialID = 8

type = Box
Aero Mass = 0.040000
Thermal Mass = 0.040000
Diameter/Width = 0.070000
Length = 0.080000
Height = 0.010000

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

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

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

name = Smart panel
quantity = 3
parent = 1
materialID = 23
type = Box
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.020000
Length = 0.150000
Height = 0.010000

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

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

name = Payload Main Module
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 11.400000
Thermal Mass = 11.400000
Diameter/Width = 0.310000
Length = 0.540000
Height = 0.100000

name = Payload Antenna
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 3.100000
Thermal Mass = 3.100000
Diameter/Width = 0.122000
Length = 0.317000
Height = 0.121000

name = C1911 Camera and Lens
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.260000
Thermal Mass = 0.260000
Diameter/Width = 0.037000
Length = 0.072000
Height = 0.037000

name = ThrustMe NPT30-I2
quantity = 2
parent = 1
materialID = 8
type = Box
Aero Mass = 0.960000
Thermal Mass = 0.960000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.100000

name = Motorized Lightband
quantity = 1
parent = 1

materialID = 8
type = Flat Plate
Aero Mass = 0.520000
Thermal Mass = 0.520000
Diameter/Width = 0.100000
Length = 0.340000

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

name = Lumen-1
Demise Altitude = 77.996019
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel +X
Demise Altitude = 76.168256
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel -X
Demise Altitude = 76.947921
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel +Y
Demise Altitude = 77.033144
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel -Y
Demise Altitude = 77.085410
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel +Z
Demise Altitude = 77.078908
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Structural Panel -Z
Demise Altitude = 77.111491
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Corner Rails
Demise Altitude = 77.731879
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = Star tracker bracket
Demise Altitude = 77.212885
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = Star tracker
Demise Altitude = 77.465342
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = Reaction wheel bracket
Demise Altitude = 76.833275
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = DPM
Demise Altitude = 75.122653
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = DEP
Demise Altitude = 77.318978
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = Reaction wheel
Demise Altitude = 76.891905
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = Torque board
Demise Altitude = 77.681884
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = Torque Rod
Demise Altitude = 76.730750
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = Gyro
Demise Altitude = 77.049434
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = Solar Panel Hinge
Demise Altitude = 77.714068
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Keep alive panel
Demise Altitude = 76.157732
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Main solar panel (deployed)
Demise Altitude = 75.459616
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Main solar panel (body mounted)
Demise Altitude = 76.483274
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Smart panel
Demise Altitude = 77.356320
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Harness
Demise Altitude = 77.945426
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Fasteners
Demise Altitude = 77.996019
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Payload Main Module
Demise Altitude = 73.524829
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Payload Antenna
Demise Altitude = 75.655679
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C1911 Camera and Lens
Demise Altitude = 73.910090
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = ThrustMe NPT30-I2
Demise Altitude = 75.838808

Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = Motorized Lightband
Demise Altitude = 77.027532
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

=============== End of Requirement 4.7-1 ===============
07 26 2024; 17:18:24PM Project Data Saved To File