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Orbital Debris Assessment Report (ODAR) AprizeSat-11 and AprizeSat-12 November 9, 2017

Background:

Aprize Satellite Inc. ("Aprize") has built, launched and operated a series of experimental microsattellites since 2004. The next pair of satellites, AprizeSats-11 and AprizeSat-12, will be launched into a polar, sun-synchronous orbit by Spaceflight on a SpaceX Falcon-9 vehicle in February 2018.

After considering the possibility of orbital debris and contamination, Aprize can provide the following information: The expected operational lifetime of AprizeSat-11 and AprizeSat-12 is five years. With a perigee altitude of 575 km and an apogee altitude of 575 km, the Aprize experimental satellites are calculated to re-enter the Earth's atmosphere and burn up completely in less than seven years. The actual orbital lifetime will be reduced by the presence of four solar arrays and eight deployable antenna elements that will significantly increase satellite drag and dissipate energy. Due to its higher orbital inclination angle and higher altitude, there is no possibility of collision between these Aprize satellites and the International Space Station.

Technical Information:

1. The Aprize satellites will be disposed of by uncontrolled atmospheric re-entry.
2. Due to the small size of the Aprize satellites (10 by 10 by 34 centimeters) and soft metal structure (Aluminum), the entire satellite will burn up and be consumed due to atmospheric heating. No large or small pieces of the spacecraft will survive to the Earth's surface.
3. There is 0% probability of human casualty resulting from surviving fragments of the satellites due to the fact that all pieces will disintegrate during atmospheric re-entry.
4. These conclusions are based on the formulas and calculations in NSS 1740.14, *NASA Guidelines and Assessment Procedures for Limiting Orbital Debris*, dated August 1995.
5. The assumptions and parameters used in developing the estimates are:
 - a. Apogee 575 km
 - b. Perigee 575 km
 - c. Inclination 97.52 degrees
 - d. Mass 4 kg
 - e. Area 0.0884 square meters
 - f. Appendages 4 deployable solar arrays and 8 deployable antenna elements.
 - g. Area²/Mass 0.0221 m²/kg



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6. The NASA Debris Assessment Software confirmed that the AprizeSat spacecraft satisfies all of the Requirements for Limiting Orbital Debris including:
 - a. Mission-Related Debris Passing Through LEO
 - b. Mission-Related Debris Passing Near GEO
 - c. Long-Term Risk from Planned Breakups
 - d. Probability of Collision With Large Objects
 - e. Probability of Damage from Small Objects
 - f. Postmission Disposal
 - g. Casualty Risk from Reentry Debris
7. The results from running the NASA Debris Assessment Software are provided in Figure 1.

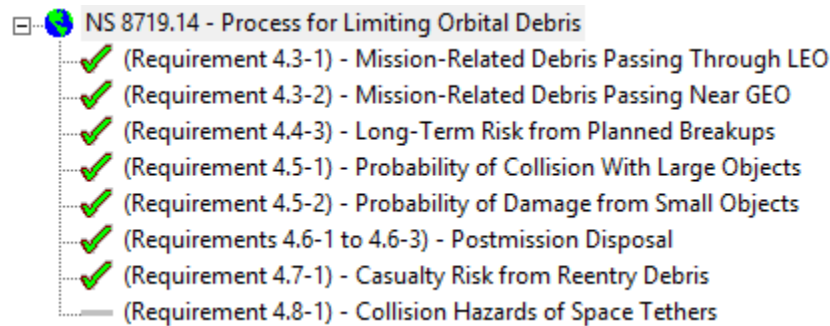


Figure 1. Aprize Satellites Satisfy All of the NASA Debris Assessment Requirements

Orbital Debris Mitigation Requirement Analysis Results

In accordance with the **U.S. Government Orbital Debris Mitigation Standard Practices**, the following information regarding the operation of the Aprize satellites is hereby submitted:

Requirement 1. Control of Debris Released During Normal Operations.

- 1.1. *For all operational orbit regimes:* The Aprize spacecraft are designed to eliminate the release of any debris in any dimension during its orbital lifetime.

Requirement 2. Minimizing Debris Generated BY Accidental Explosions.

- 2.1. *Limiting the risk to other space systems from accidental explosions during mission operations:* The Aprize satellites have no on-board fuels, no explosives, or pressure vessels. The only stored energy on board the satellites is contained in the eight

lithium-ion batteries, which will be fully discharged at end-of-life. Similar lithium-ion cells have been used successfully on many small satellite programs without incident. The probability of accidental explosions during and after mission operations has been assessed and limited by the satellite design. Thus, the Aprize satellites will not generate additional sources of debris due to accidental explosions.

- 2.2. *Limiting the risk to other space systems from accidental explosions after completion of mission operations.* After completion of its mission operations, the Aprize satellites will remain dormant until they re-enter the atmosphere and disintegration during their return to Earth.

Requirement 3. Selection of Safe Flight Profile and Operational Configuration.

- 3.1 *Collision with large objects during orbital lifetime.* The probability of the Aprize satellites colliding with an object larger than 1 meter is less than 0.0002% as shown in Figure 3.

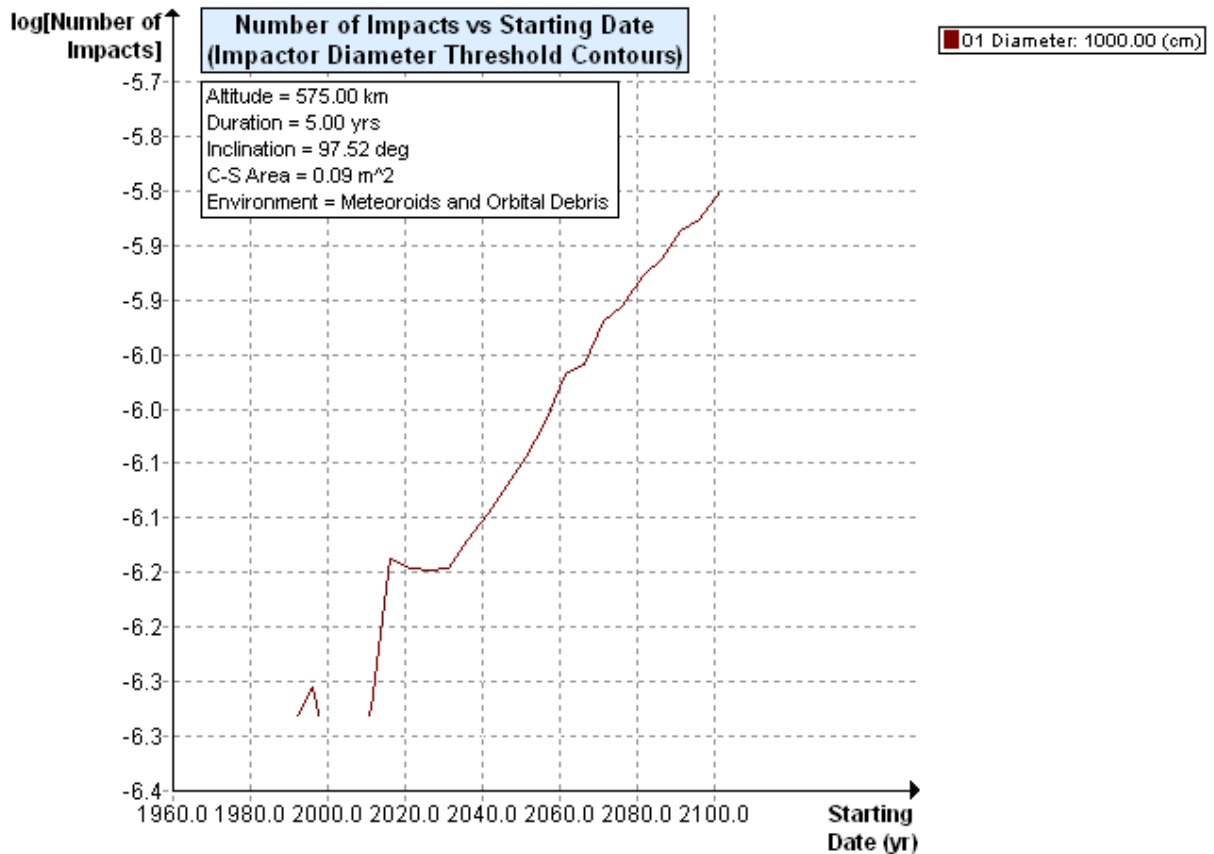


Figure 3. Log Number of Impacts of 1 Meter Objects Vs. Time

3.2 *Collision with small debris during mission operations:* Collision with debris smaller than 1 cm diameter will not prevent post-mission disposal as the Aprize satellites will re-enter the atmosphere without any action taken by the spacecraft itself. Figures 4, 5 and 6 show the probability of impact with small debris.

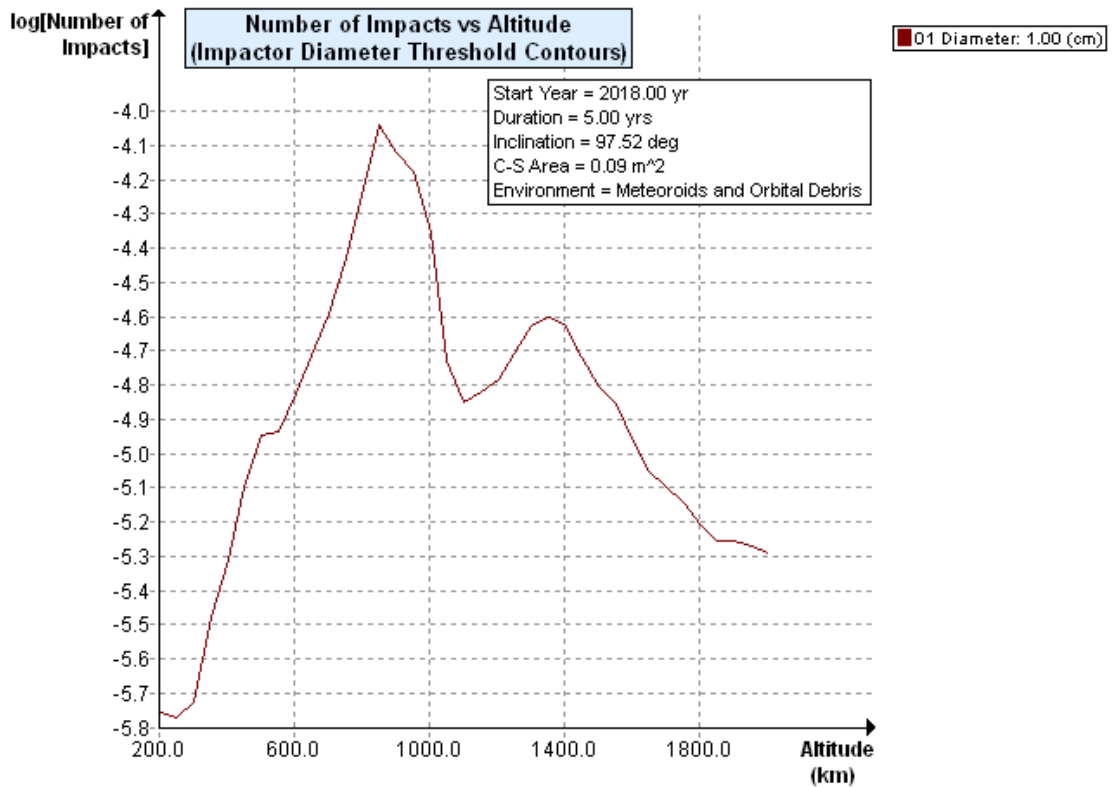


Figure 4. Log Number of Impacts of 1 cm Objects Vs. Satellite Altitude

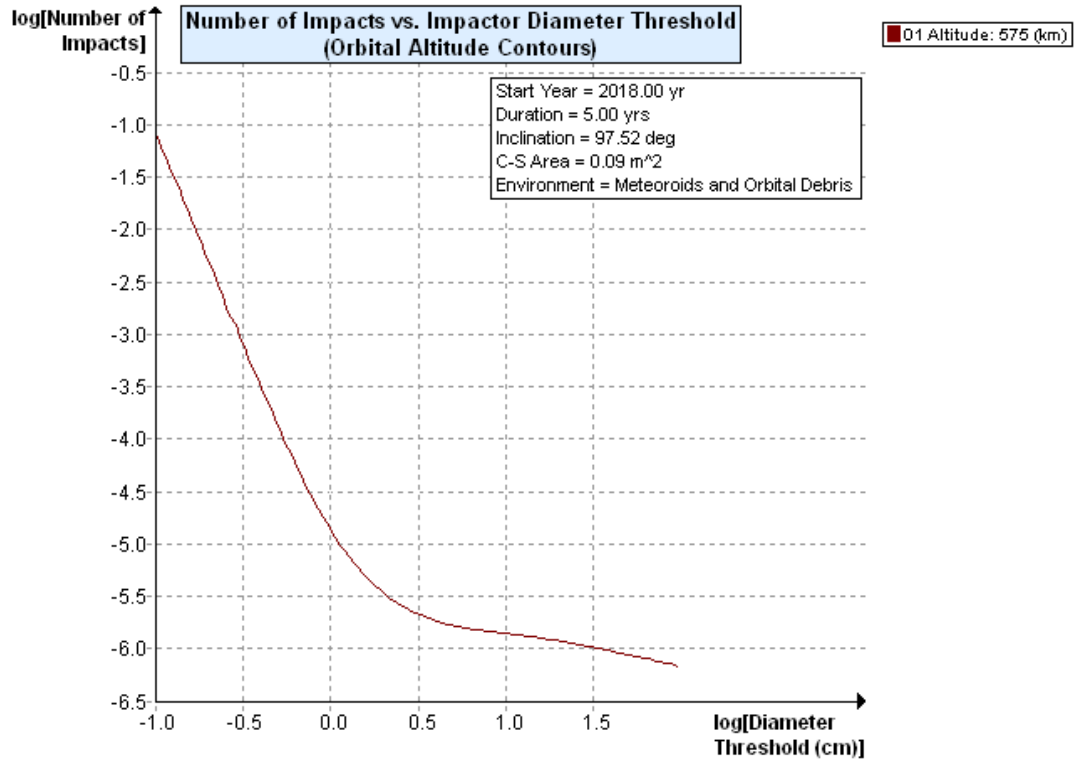


Figure 5. Log Number of Impacts Vs. the Log Diameter of Particles

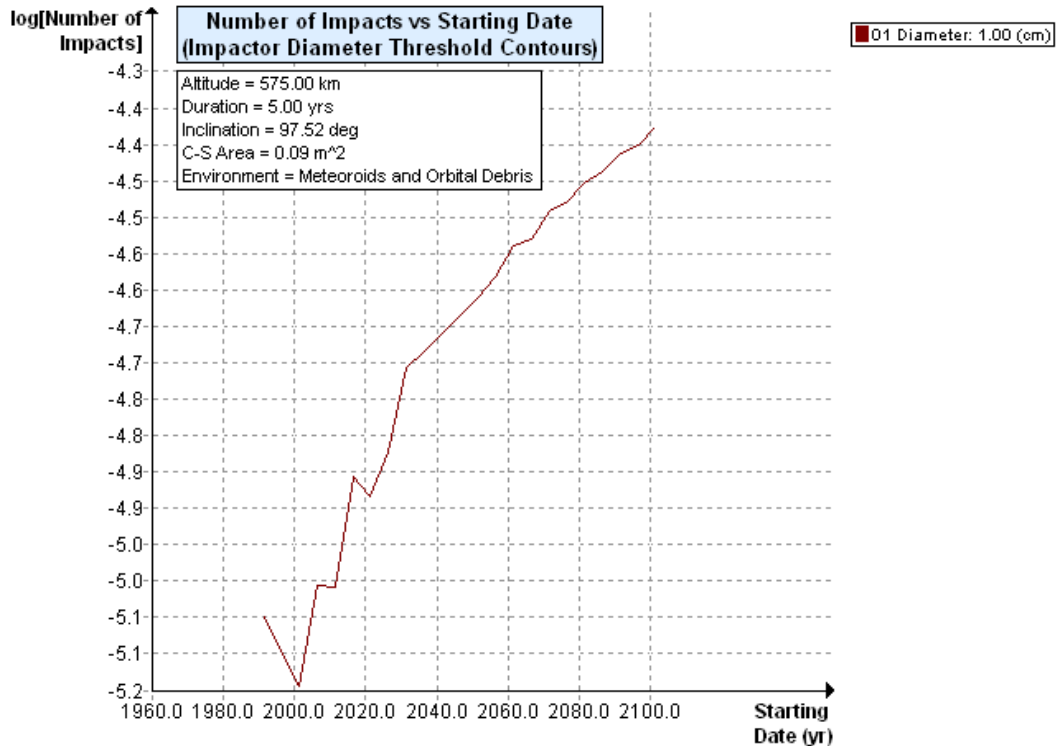


Figure 6. Log Number of Impacts of 1 cm Objects Vs. Time

- 3.3 *Tether systems:* The Aprize satellites do not deploy any tether systems.
- 3.4 *Measures taken to avoid in-orbit collisions:* The Aprize satellites will be launched into orbit along with multiple other spacecraft. All coordination to avoid in-orbit collisions between the satellites during and immediately after deployment is done by the launch provider.

Requirement 4. Postmission Disposal of Space Structures.

- 4.1 *Disposal for final mission orbits:*
 - a. Atmospheric reentry option: The requirement is to “Leave the structure in an orbit in which, using conservative projections for solar activity, atmospheric drag will limit the lifetime to no longer than 25 years after completion of mission.”

Using conservative projections for solar activity and atmospheric drag, the total orbital lifetime of the Aprize satellites will be less than 6 years, which is 1 years after completion of its mission operations. The deployable solar arrays and antennas will increase the overall atmospheric drag causing the satellites to

decay faster than the orbital prediction model. A plot of the orbital decay history for the Aprize satellites calculated using the NASA Debris Assessment Software is shown in Figure 7.

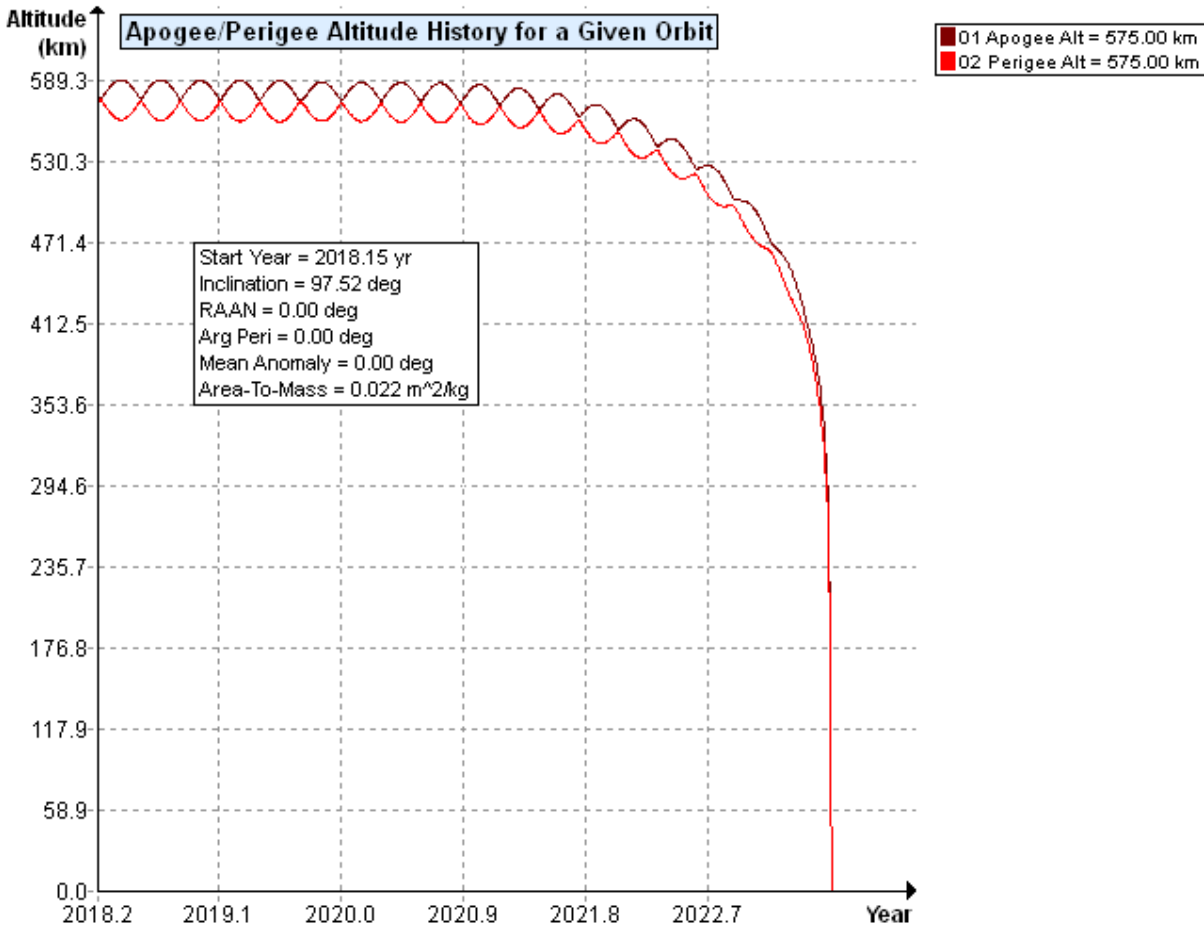


Figure 7. NASA DAS Predicts the Aprize Satellites Will Decay in About 6 years; Assuming Average Ram Area

Human casualty risk: The requirement is that “If a space structure is to be disposed of by reentry into the Earth’s atmosphere, the risk of human casualty will be less than 1 in 10,000.”

According to the calculations made with the NASA Debris Assessment Software there will be no risk of human casualty as the small spacecraft will completely disintegrate at an altitude of 66.5 km during re-entry. The results of these calculations are shown in Figure 10.



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| Component Data | | | | | | | |
|----------------|-------------|----------|------------------|--------------|--------------|----------------|--------|
| | Name | Quantity | Material Type | Object Shape | Thermal Mass | Diameter/Width | Length |
| | | | | | (kg) | (m) | (m) |
| 1 | Root Object | 1 | Aluminum 6061-T6 | Box | 4 | 0.1 | 0.34 |

| Output | | | | |
|-------------|--------------|---------------|-------------------|------------|
| Object | SubComponent | Demise | Total Debris | Kinetic |
| Name | Object | Altitude (km) | Casualty Area ... | Energy (J) |
| Root Object | | 66.5 | 0.00 | 0 |

Figure 8. The AprizeSats Will Burn Up and Disintegrate at an Altitude of 66.5 km

- b. Maneuvering to a storage orbit: Not Applicable
- c. Direct retrieval: Not Applicable

4.2 *Tether systems*. Not Applicable

Sincerely,

Dino A. Lorenzini
President, Aprize Satellite Inc.