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Orbital Debris Assessment Report (ODAR)

File #: 0220-EX-CN-2018

Background:

After considering the possibility of orbital debris and contamination, SpaceQuest is able to provide the following information: The expected operational lifetime of the BRIO satellite is about 5 years. With a perigee altitude of 575 km and an apogee altitude of 575 km, the BRIO experimental satellite is calculated to re-enter the Earth's atmosphere and burn up completely in 6 years or less. The actual orbital lifetime will be reduced by the presence of four solar arrays and four deployable antenna elements that will increase the satellite drag and dissipate energy.

The BRIO satellite will be in a polar, sun-synchronous orbit. Due to BRIO's higher orbital inclination angle and higher altitude, there is no possibility of collision between the SpaceQuest satellites and the International Space Station.

Technical Information:

1. The SpaceQuest BRIO satellite will by disposed of by uncontrolled atmospheric re-entry.

2. Due to the small size of the satellite (10 by 10 by 34 centemeters) 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 satellite 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 degees
   d. Mass 5 kg
   e. Area 0.09 square meters
   f. Appendages 4 deployable solar arrays and 4 deployable antenna elements.
   g. Area/Mass 0.018 m^2/kg

6. The NASA Debris Assessment Software confirmed that the BRIO spacecraft satisfies all of the Requirements for Limiting Orbita 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.

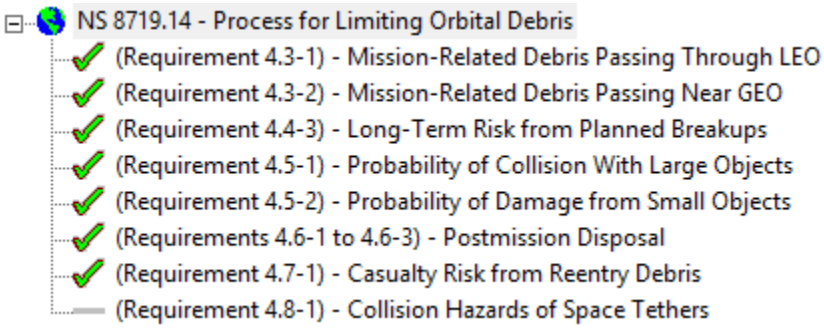

Figure 1. SpaceQuest Satellite Satisfy All of the NASA Debris Assessment Requirements

Orbital Debris Mitigation Requirement Analysis Results

In accordance with the ***U.S. Goverment Orbital Debris Mitigation Standard Practice***s, the following information regarding the operation of the BRIO satellite is hereby submitted:

Requirement 1. Control of Debris Released During Norma Operations.

1.1. *For all oprerational orbit regimes:* The BRIO spacecraft is 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 operatons:* The BRIO satellite has no on-board fuel, no explosives or pressure vessels. The only stored energy on board the satellite 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 BRIO satellite 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 BRIO satellite will remain domant until it re-enters the atmosphere and disintegrates during its 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 SpaceQuest satellite colliding with an object larger than 1 meter is less than 0.0002% as shown in Figure 2.

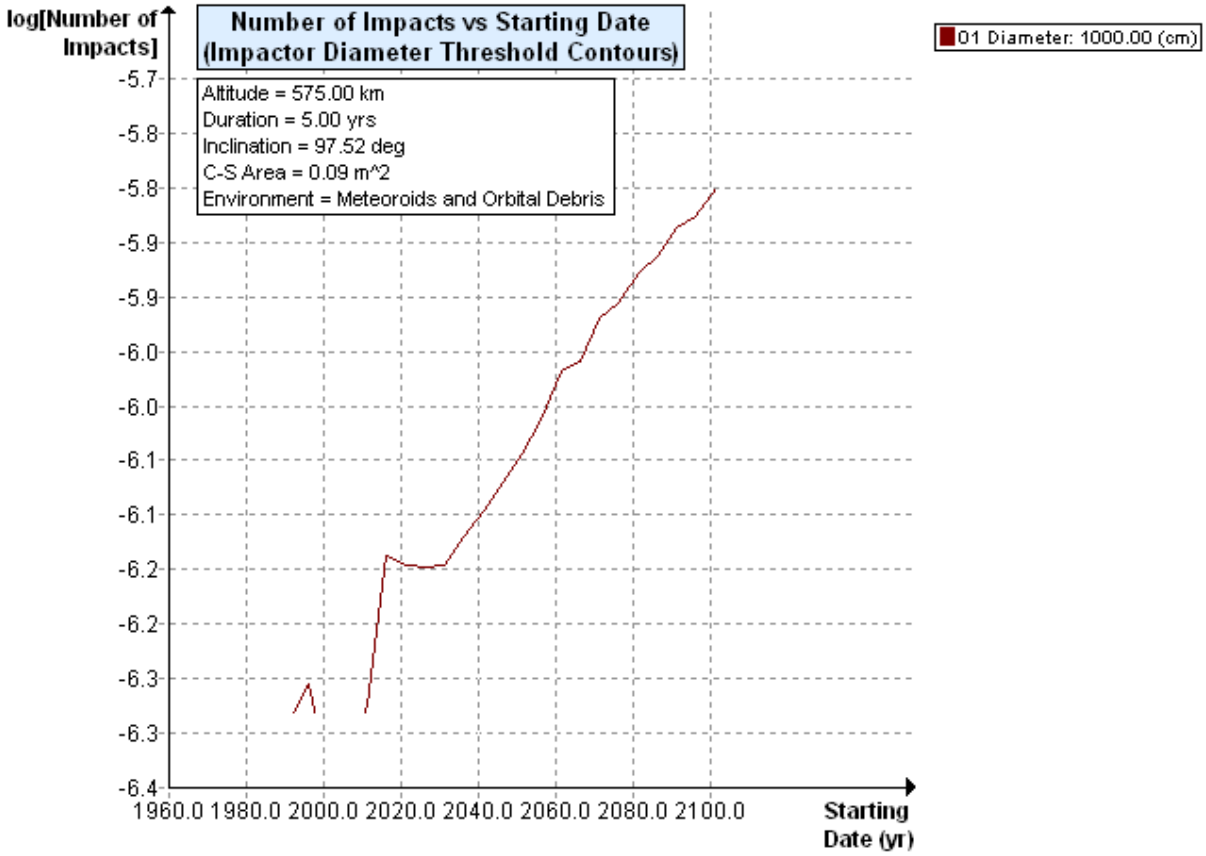

Figure 2. Log Number of Impacts of 1 Meter Objects Vs. Time

3.2 *Colision with small debris during mission operations*: Colision with debris smaller than 1 cm diameter will not prevent post-mission disposal as the SpaceQuest satellite 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.

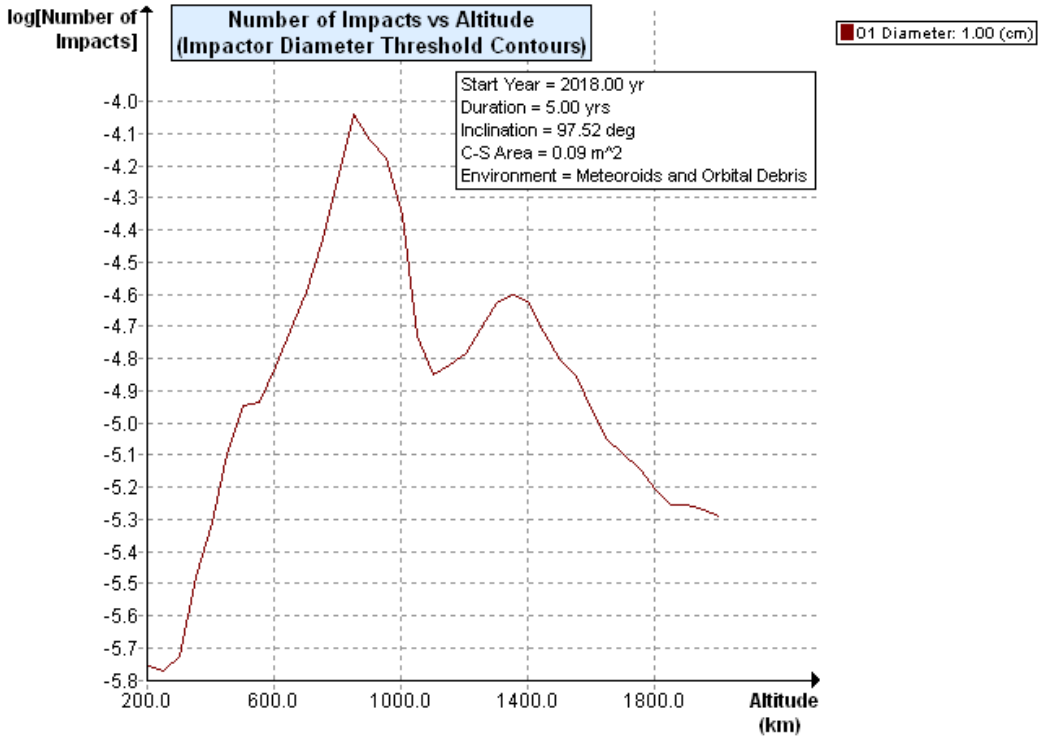

Figure 4. Log Number of Impacts of 1 cm Objects Vs. Satellite Altitude

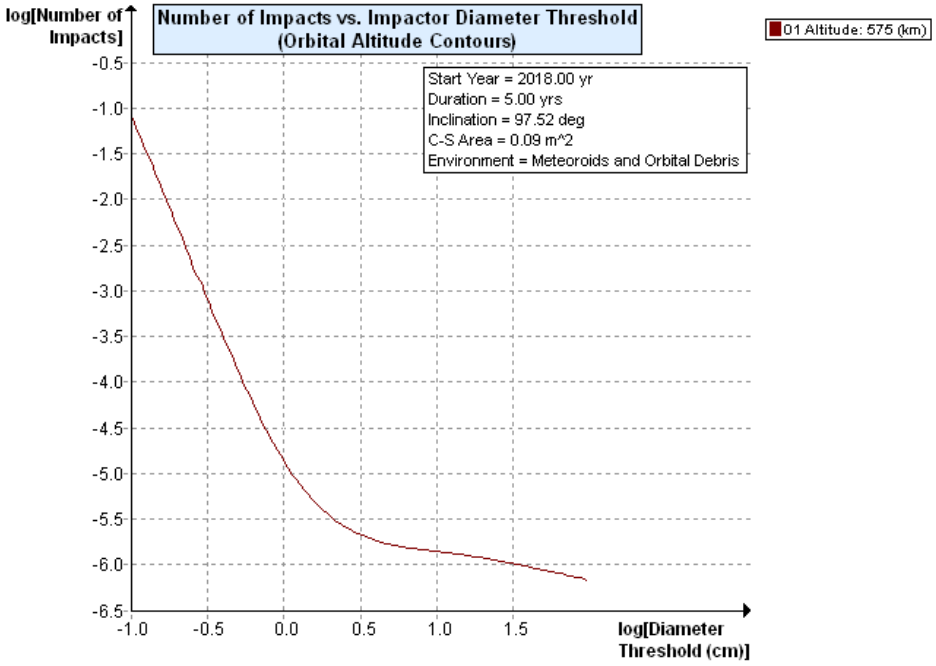

Figure 5. Log Number of Impacts Vs. the Log Diameter of Particles

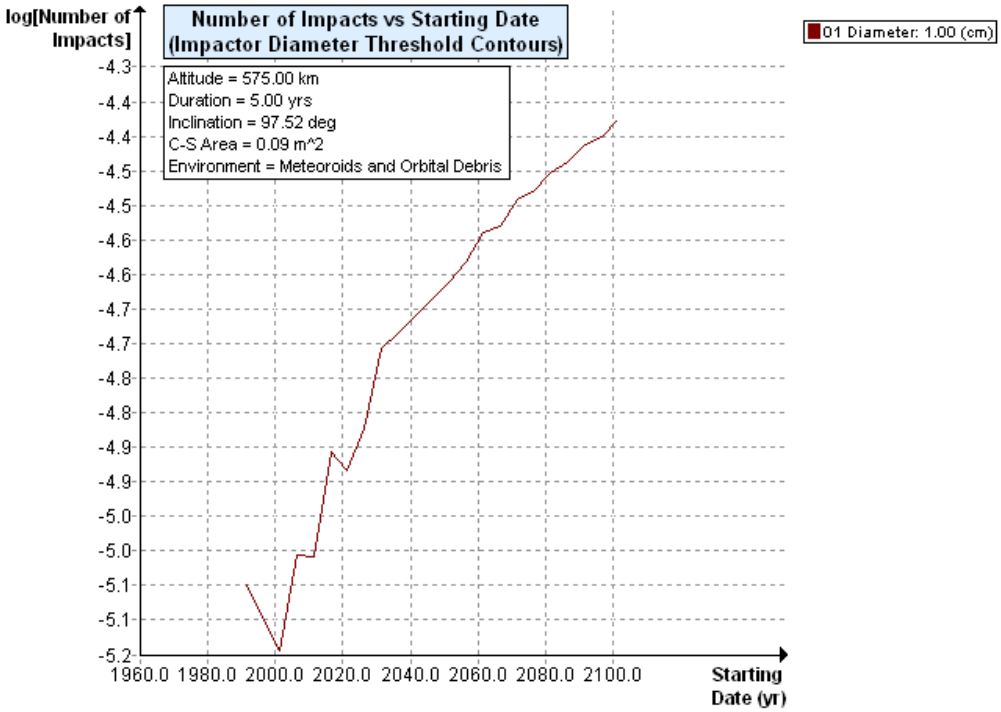

Figure 6. Log Number of Impacts of 1 cm Objects Vs. Time

3.3 *Tether systems:* The SpaceQuest satellite does not deploy any tether systems.

3.4 *Measures taken to avoid in-orbit collisions:* The SpaceQuest satellite will be launched into orbit along with multiple other spacecraft. All coordination to avoid in-orbit collisions between the satellite during and imediately 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 nolonger than 25 years after completion of mission”

Using conservative projections for solar activity and atmospheric drag, the total orbital lifetime of the BRIO will be less than 7 years, which is 2 years after completion of its mission operations. The deployable solar arrays and antennas will increase the overal atmospheric drag causing the satllite to decay faster than the orbital prediction model. A plot of the orbital decay history for the SpaceQuest satellite calculated using the NASA Debris Assessment Software is shown in Figure 7.

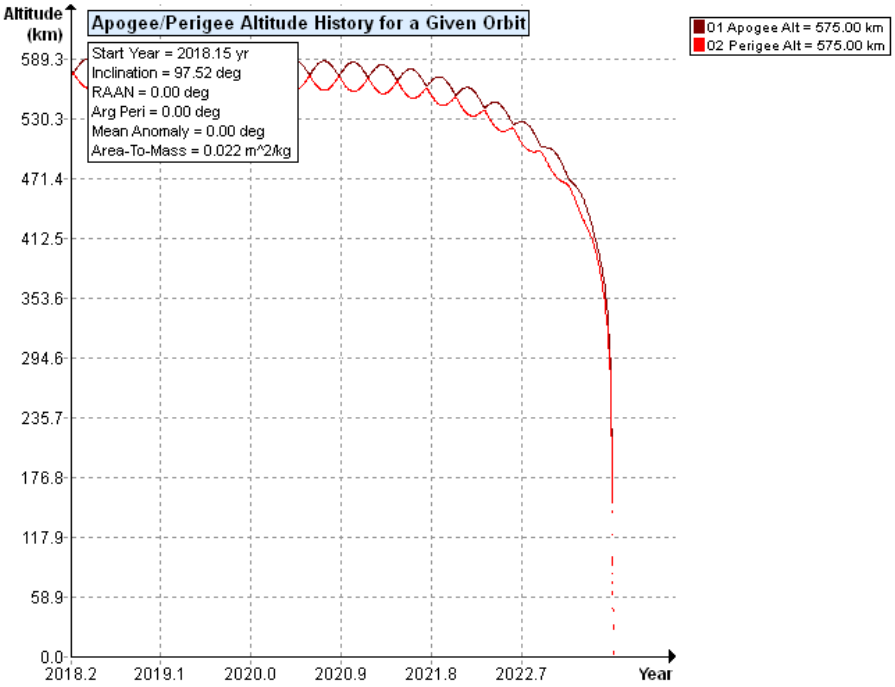

Figure 7. NASA DAS Predicts the SpaceQuest Satellite Will Decay in About 7 years; assuming average ram area.

Human casuality 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 casuality 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 8.

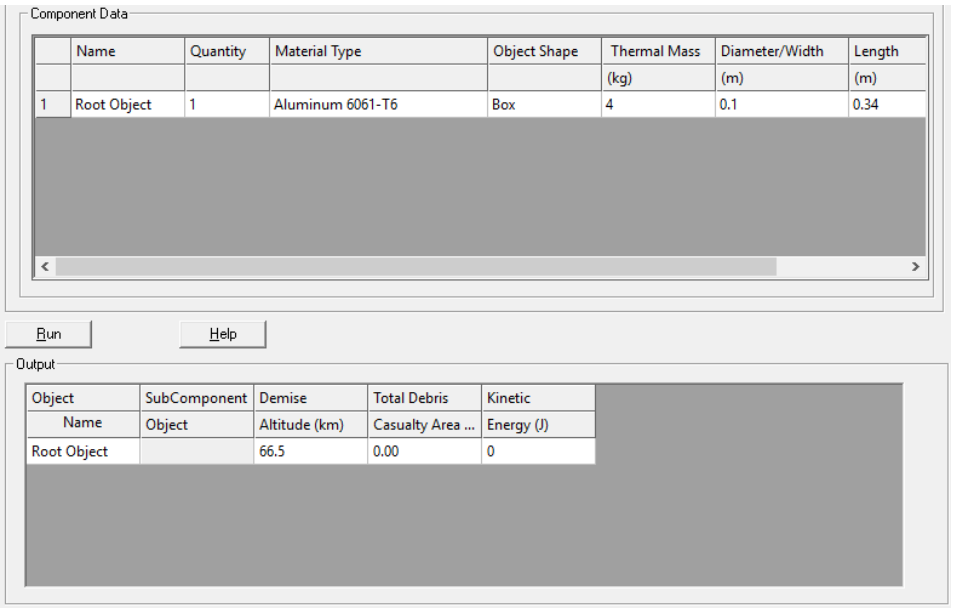

Figure 8. BRIO Will Burn Up and Disintegrate at an Altitude of 66.5 km

b. Maneuvering to a storage orbit: Not Applicable

c. Direct retrieval: Not Applicable

4.2 *Tether systems*. Not Applicable

Sincerely,

Dino A. Lorenzini
President,
SpaceQuest, Ltd.