How Can Small Satellites be used to Support Orbital Debris Removal Goals Instead of Increasing the Problem?

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Orbital Debris Problem

• **Background**
  - Orbital debris refers to material that is on orbit as the result of space initiatives but is no longer serving any function. Debris poses increasing risk to existing and new spacecraft.

• **Obsolete man-made objects in Earth Orbit**
  - 19,000 objects > 10 cm
  - 500,000 objects > 1 cm
  - Tens of Millions < 1 cm

• **Most Debris Concentrated in Low Earth Orbit**

• **Debris Population Estimates and Tracking**
  - Objects > 10 cm **tracked by** US Space Surveillance Network
  - Objects ≥ 3 mm **detected by** ground based radars
  - Smaller object populations estimated based on impact features on returned spacecraft

• **Particle Velocity**
  - Average Impact Speed = 10 km/sec
    - 1 cm objects could cause catastrophic failure
    - < 1 cm objects may cause significant damage
    - > 10 cm objects are tracked, spacecraft can maneuver around them

http://orbitaldebris.jsc.nasa.gov/index.html
• Mitigation of Medium Size (1 to 10cm) Orbital Debris in Low Earth Orbit (< 2000 km)
• 1 to 10cm debris: Cannot be Effectively Shielded Against nor Consistently Maneuvered Around
• Non Tracked Objects: Too Difficult to Observe with Ground-Based Telescopes, Radars
• >1 cm debris: Cause Catastrophic Failure (loss of functionality of satellite due to the impact)
• Low Earth Orbit (LEO) Selected: Most concentrated area

• Four approaches to reducing Orbital Debris issues
  • De-orbiting (1)
  • Orbital lifetime reduction (2)
  • Repositioning into "disposal" orbits (3)
  • Active removal of debris from orbit (4)

• Not compatible with Small Sat use
  • Laser
    – Ground Based
    – UAV Based
    – Space Based
  • Aerogel Capture
  • Solar Concentrator

• Compatible with Small Sat use
  • Multi-Layer Sphere

Trade Study Scorecard - Summary

<table>
<thead>
<tr>
<th>Point system: 10 highest - 1 Lowest</th>
<th>Ability to remove 0.5 to 10 cm debris (5X)</th>
<th>Ratio of Debris Removal (2X)</th>
<th>Cost to remove debris (high cost = low score)</th>
<th>Ability to remove debris in LEO (1X)</th>
<th>Expected Support From Government Agencies (6X)</th>
<th>Technology Readiness Level (20)</th>
<th>Low energy approach (3X)</th>
<th>ROM Cost to TRL-6 (high cost = low score)</th>
<th>Ability to 3D print debris (4X)</th>
<th>Number of subsystems (1X)</th>
<th>Total Score</th>
<th>Ranking</th>
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<tbody>
<tr>
<td>1 Multi-Layer Sphere</td>
<td>9</td>
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Multi-Layer Sphere—Debris Removal Concept

- Operational Applications
  - A lightweight, multi-layer sphere deployed in space can break up large particles, creating smaller particles to break up other particles, causing effective ‘Mass Fission’ Debris depletion.
  - Deployed around a spacecraft, it can break up large particles into shieldable debris (note only half of the sphere is shown for clarity of layers).
  - The MLS system can be used to provide additional protection to the International Space Station.
**Multi-Layer Sphere—Debris Removal Concept**

- **Operational Use**
  - (1) Around a critical asset acting to intercept & pulverize debris
  - (2) Roam in space, sweeping out and similarly pulverizing debris
  - (3) Stored on orbit for future use to prevent a catastrophic collision

- **MLS Construction**
  - Specifically spaced discrete material
  - Break-up large particle debris that later impacts other internal layers
  - Impacts other large particles **creating small shield-able debris particles**

- **Target Size and Orbit**
  - Orbital debris in low-Earth orbit:
    - Diameter: 1 to 10 cm
    - Material: ~ Metallic
    - Velocities: 10 Km/sec.
Existing Test Data Demonstrates Physics

Hypervelocity Testing

6 km/s 1cm Diameter Particle During Impact Test

Hydro Code Simulation

6 km/s 1cm Diameter Particle During Hydro Code Simulation

**Low Earth Orbit Focused**

**Highest Particle Density Location**
- Mitigation of orbital debris in LEO (< 2000 km) with highest particle density > 1 cm.
- Particle Flux for 1 cm. Particles Peaks at ~ $4 \times 10^{-5}$/m$^2$/Year at 900 Km.

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*ORDEM2000 vs. Haystack data (1999, objects ≥1 cm).*

Required Maneuverability

• Sweep cross-section of LEO torus orbital volume
• Spherical Shape => No special pointing requirements during operations
• Maneuverability requirements higher if spacecraft used as protector shield for high value space assets
Conclusions

• **Orbital Debris Problem Becoming Critical**
  - Since 2005, the space debris environment has been unstable and began a collision cascade effect per NASA.
  - Impact is due to wide range of size distribution (1cm and larger).
  - Need resolution plan developed and implemented.

• **MLS Mitigation Strategies via Small Satellite**
  - Mission Life >3 years
  - Accommodate ROM of 100,000 impacts per sphere
  - Multiple spacecraft needed to mitigate LEO debris particles

• **Continued Awareness & Support to Resolve**
  - NASA effort to define and track orbital debris problem
  - Presidential support to address an international need