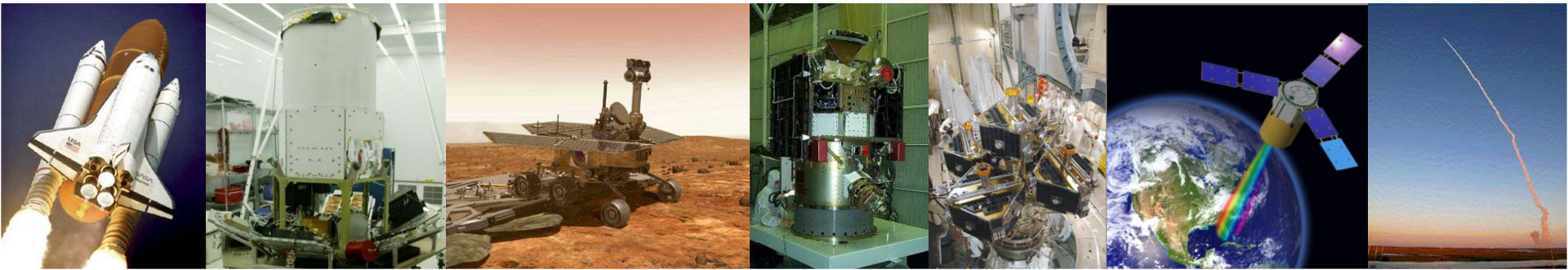
How Can Small Satellites be used to Support Orbital Debris Removal Goals Instead of Increasing the Problem?

Jose Guerrero, Jon Manash, Kevin McKee, Matt Russell, Steve Stone and Doyle Towles

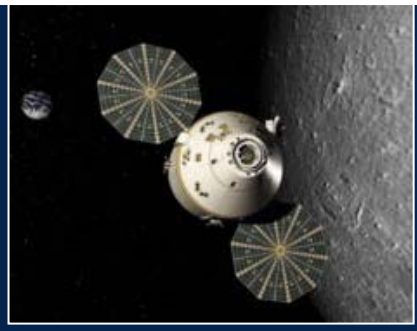
Jose.Guerrero@ATK.com (626) 470-5134
Kevin.McKee@ATK.com (626) 470-5072

ATK Spacecraft, Systems and Services
370 N. Halstead St., Pasadena, Ca. 91107;

Paper Ref. SSC10-II-7



ATK Aerospace Systems



Clearfield, UT

Aerospace Systems HQ
Magna, UT

Magna, UT
Precision Structures

Promontory, UT

Colorado Springs, CO
Field Office

Lancaster, CA
Field Office

Pasadena, CA
Engineering Services (JPL)

Commerce, CA
Propulsion Tanks

VAFB

Goleta, CA
Solar Arrays and Deployables

El Segundo, CA
LA Field Office

Corona, CA
Panels / Bus Structures

San Diego, CA
Precision Structures
Ceramics / Reflectors

Omaha, NE
Field Office

Albuquerque, NM
Field Office

Beltsville, MD
Engineering Services
Spacecraft Systems
Thermal Systems

Hampton, VA
Engineering Services (LaRC)

Huntsville, AL

KSC, CCAFS & FL

Houston, TX
Field Office

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

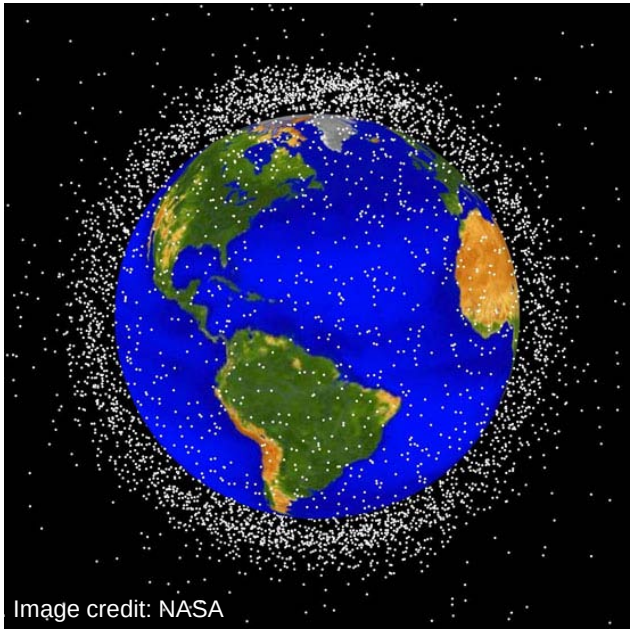


Image credit: NASA

http://orbitaldebris.jsc.nasa.gov/index.html

ATK Trade Studies

- 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

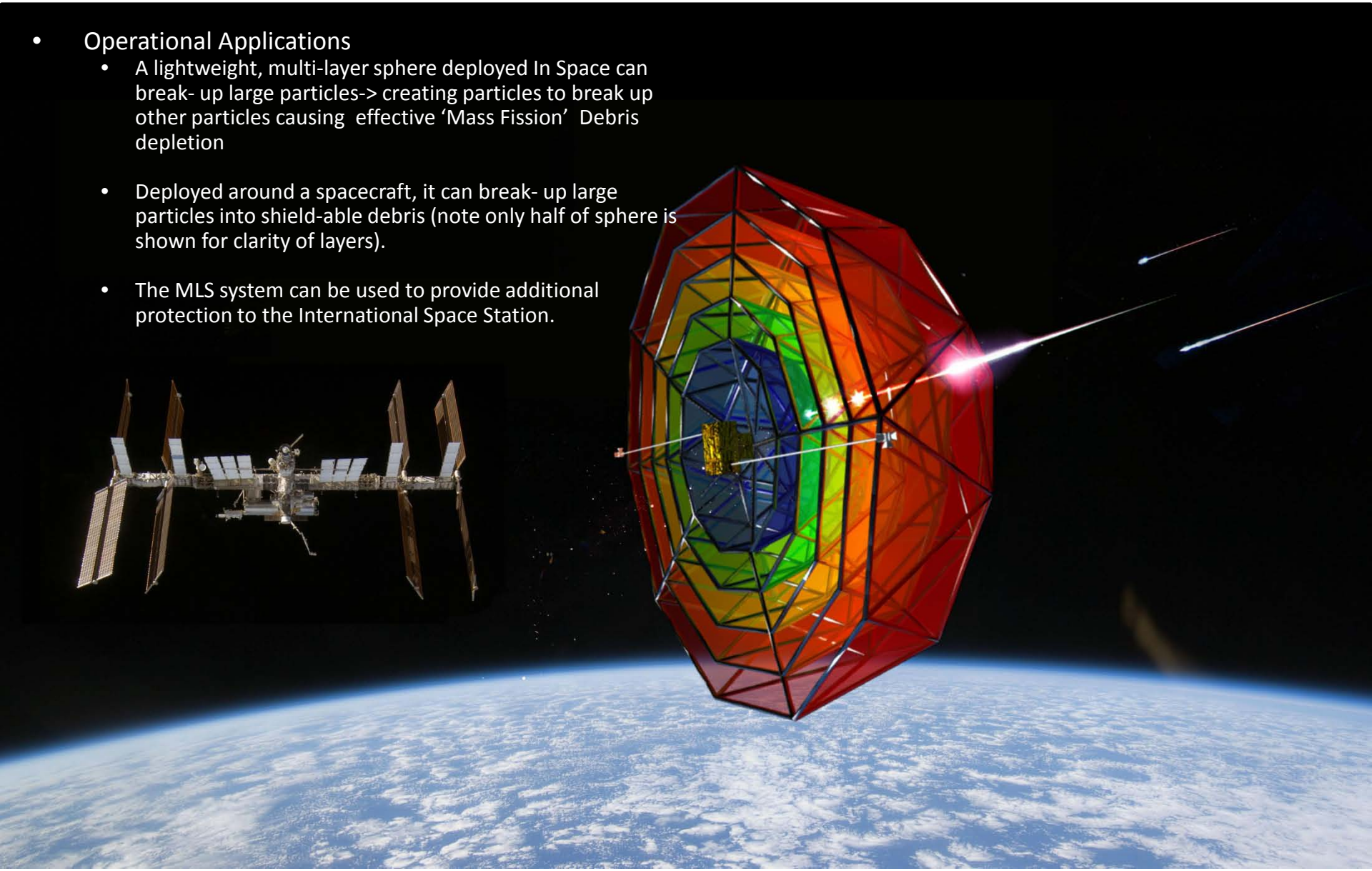
Trade Study Scorecard - Summary

	Point system: 10 highest - 1 Lowest	Ability to remove 0.5 to 10cm debris (5X)	Rate of Debris Removal (2X)	Number of objects removed during life Span per unit	Cost per debris removal (high cost = low score)	Ability to remove debris in LEO (2X)	Expected Support From Government Agencies (5X)	Technology Readiness Level (3X)	International accepted approach (3X)	Low energy approach (2x) (hign energy = low score)	ROM Cost to TRL-6 (hign cost = low score)	Ability to track debris	Amount of research funds awarded	Number of subsystems (-1X)	Ability to test in laboratory	Life Span of Solution in years (2X)	Total Score	**Ranking**
2	**Multi-Layer Sphere**	9	7	7	10	8	9	7	7	8	8	8	5	2	10	7	250	1
4	**Ground-Based Laser**	8	8	10	4	9	9	7	5	3	5	6	10	10	8	10	220	2
5	**Space Based USP Laser**	10	9	8	4	10	8	7	2	5	2	9	9	10	9	5	213	3
6	**Aerogel Capture System**	5	4	5	6	6	7	7	7	7	7	5	8	3	10	7	197	4
7	**UAV-Based Fiber Laser**	7	6	6	5	8	9	4	4	4	4	4	5	10	8	5	179	5
8	**Solar Concentrator**	6	5	8	3	7	6	4	2	9	2	9	4	5	5	5	163	6

- **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

Multi-Layer Sphere– Debris Removal Concept

- Operational Applications
  - A lightweight, multi-layer sphere deployed In Space can break- up large particles-> creating particles to break up other particles causing effective ‘Mass Fission’ Debris depletion
  - Deployed around a spacecraft, it can break- up large particles into shield-able debris (note only half of sphere is shown for clarity of layers).
  - The MLS system can be used to provide additional protection to the International Space Station.

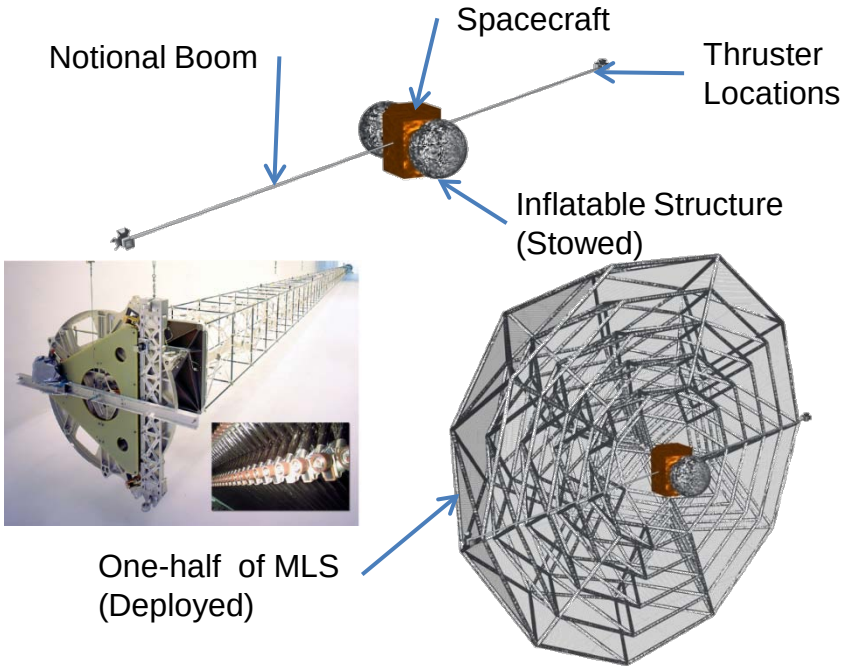


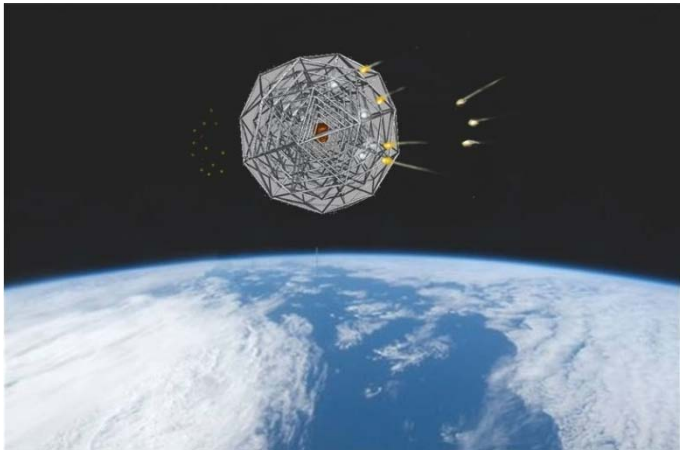
Multi-Layer Sphere– Debris Removal Concept

- **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**

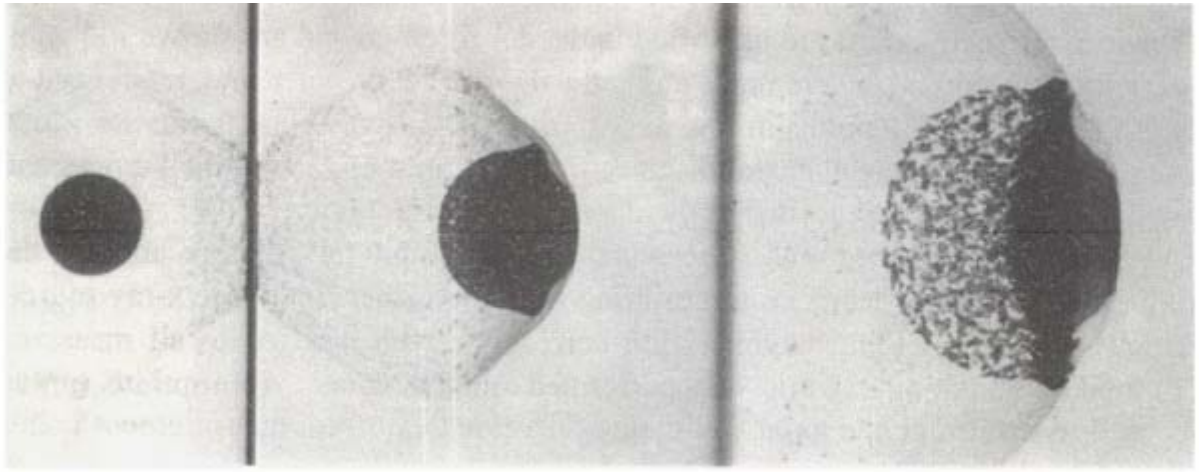
- **Target Size and Orbit**
  - Orbital debris in low-Earth orbit:
    - Diameter: 1 to 10 cm
    - Material: ~ Metallic
    - Velocities: 10 Km/sec.





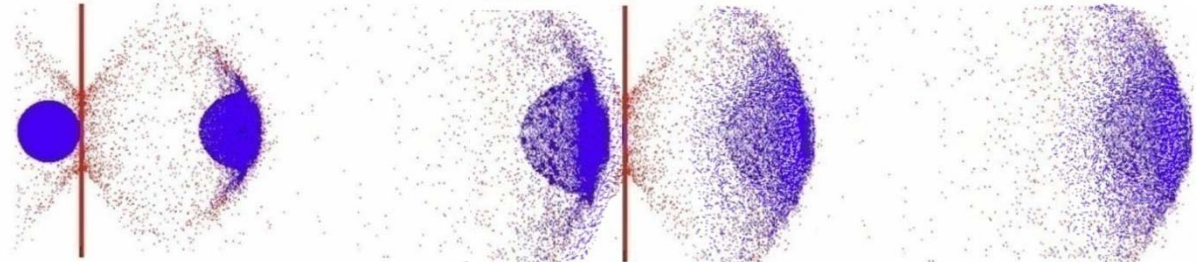
Existing Test Data Demonstrates Physics

Hypervelocity Testing



6 km/s 1cm Diameter Particle During Impact Test

Hydro Code Simulation



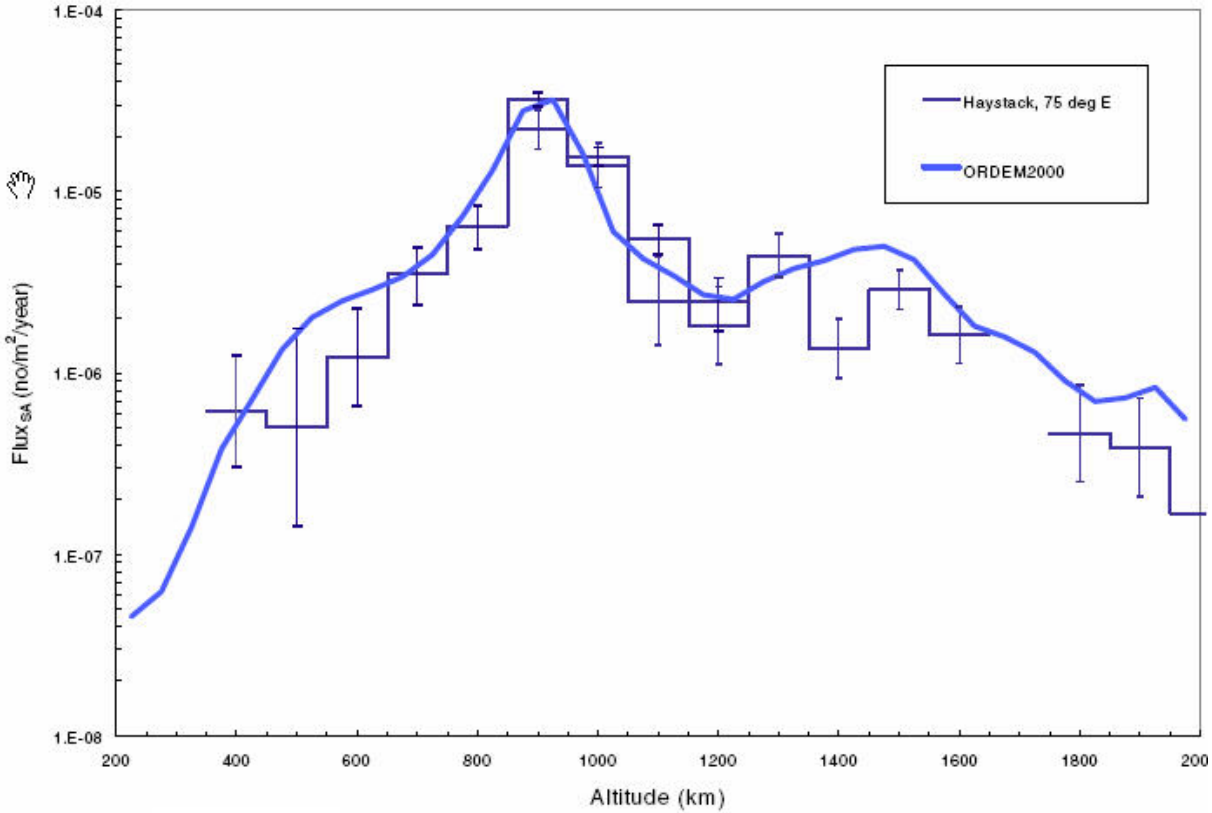
6 km/s 1cm Diameter Particle During Hydro Code Simulation

Testing and simulation from: S.R. Beissel, C.A. Gerlach, G.R. Johnson, "Hypervelocity impact computations with finite elements and mesh free particles," International Journal of Impact Engineering 33 (2006) 80-90.

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 ~ 4x 10^-5/M^2/Year at 900 Km.

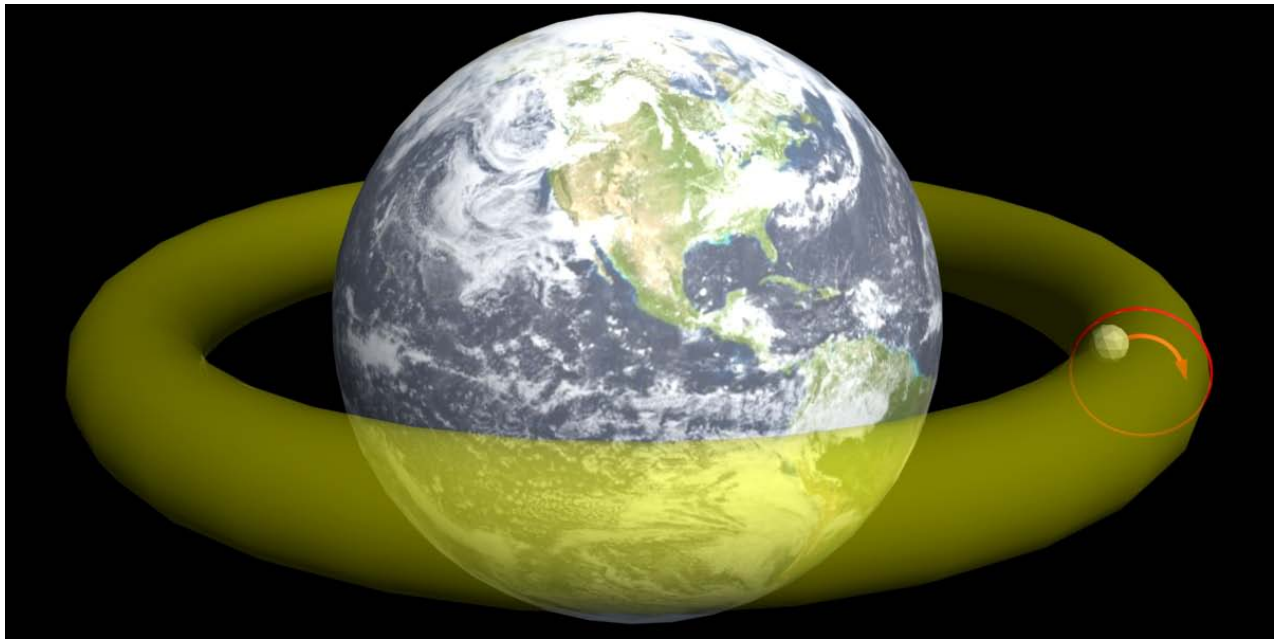


ORDEM2000 vs. Haystack data (1999, objects ≥1 cm).

http://ston.jsc.nasa.gov/collections/TRS/_techrep/TP-2002-210780.pdf

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