Orbital Debris & Space Traffic Control

Gene Stansbery
Program Manager
Orbital Debris Program Office

13th Annual FAA Commercial Space Transportation Conference
10 - 11 February 2010

United States Space Policy

- **President Ronald Reagan's update of the U.S. National Space Policy, signed January 5, 1988, was the first White House declaration to address specifically the topic of orbital debris and to recognize the need for its mitigation to preserve near-Earth space for future generations.**

- **Each succeeding president has updated and expanded upon this directive in subsequent national space policies.**

- **The most recent, signed by President George W. Bush on August 31, 2006 states:**

  Orbital debris poses a risk to continued reliable use of space-based services and operations and to the safety of persons and property in space and on Earth. The United States shall seek to minimize the creation of orbital debris by government and non-government operations in space in order to preserve the space environment for future generations. Toward that end:

  - ***Departments and agencies shall continue to follow the United States Government Orbital Debris Mitigation Standard Practices, consistent with mission requirements and cost effectiveness, in the procurement and operation of spacecraft, launch services, and the operation of tests and experiments in space;***

  - ***The Secretaries of Commerce and Transportation, in coordination with the Chairman of the Federal Communications Commission, shall continue to address orbital debris issues through their respective licensing procedures; and***

  - ***The United States shall take a leadership role in international fora to encourage foreign nations and international organizations to adopt policies and practices aimed at debris minimization and shall cooperate in the exchange of information on debris research and identification of improved debris mitigation practices.***

US Government Orbital Debris Mitigation Standard Practices

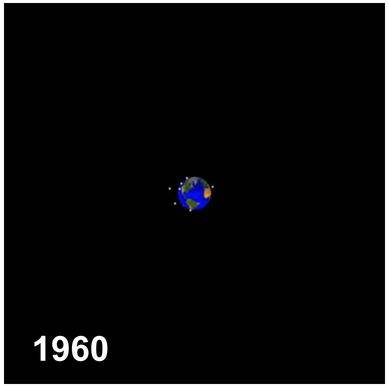
- **Approved in 2002 and applicable to all US Government Agencies**

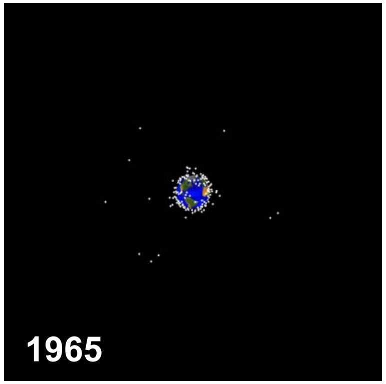
Objectives*

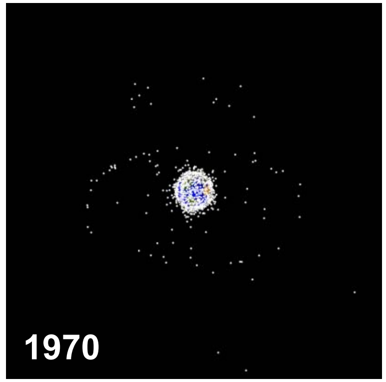
- **Objective 1 – Control of Debris Released During Normal Operations**
- **Objective 2 – Minimizing Debris Generated by Accidental Explosions**
- **Objective 3 – Selection of Safe Flight Profile and Operation Configuration**
- **Objective 4 – Postmission Disposal of Space Structures**

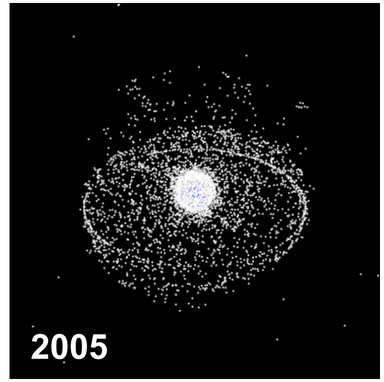
*** Full text provided in backup charts**

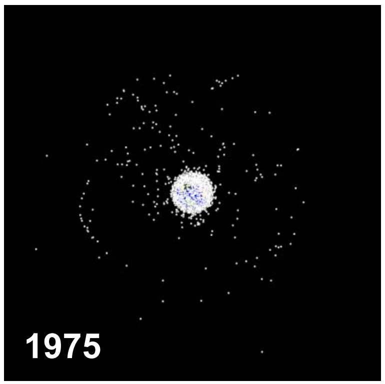
Growth of the Satellite Population

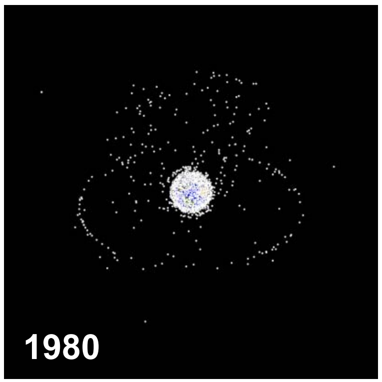


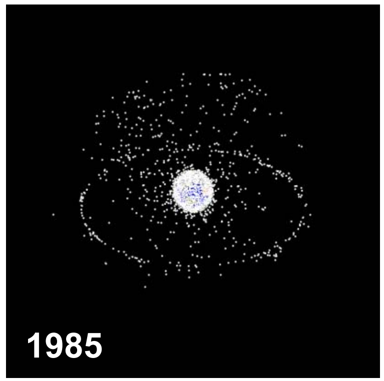


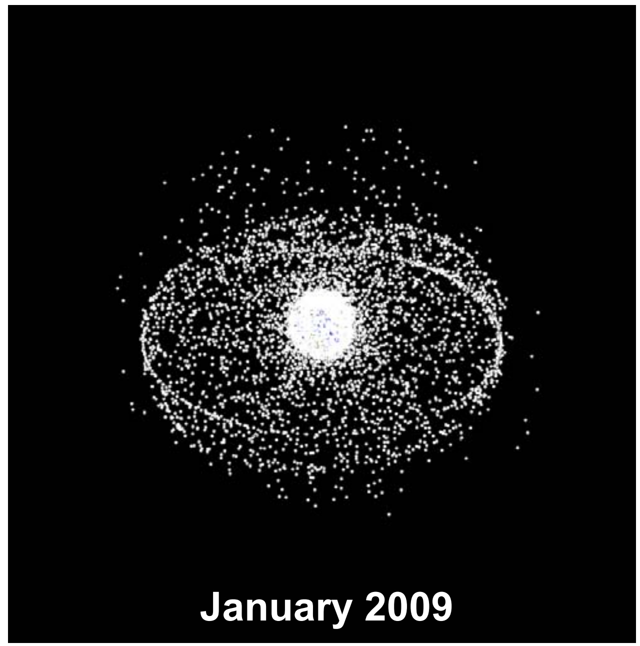


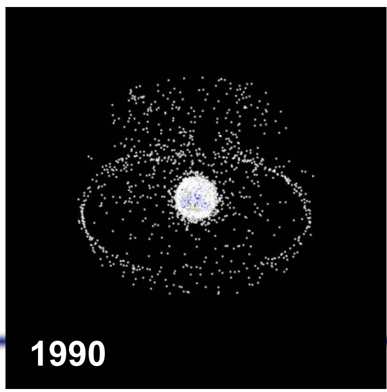


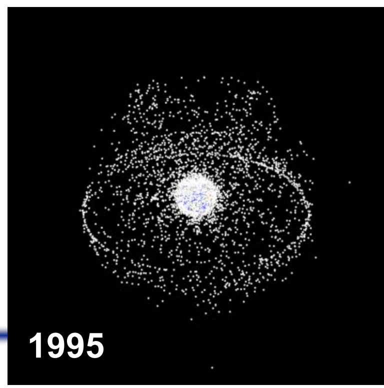


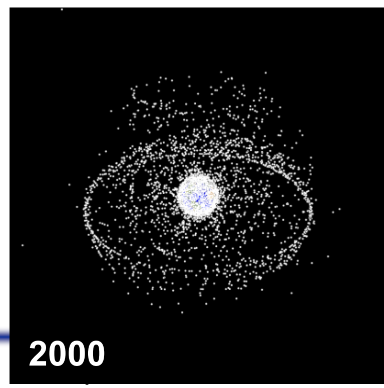








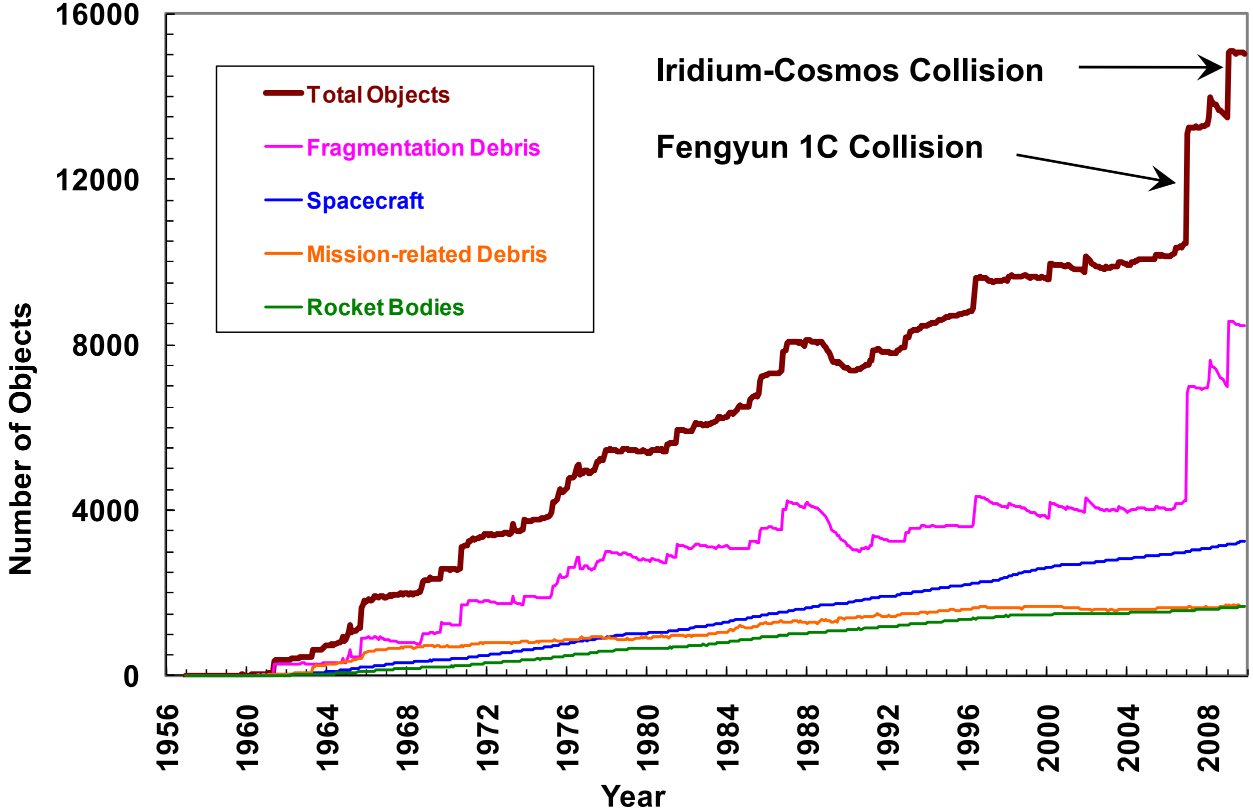




94% of Tracked Object Population are Debris

Growth of the Tracked, Cataloged Population

- **The US Department of Defense maintains a worldwide network of sensors which catalogs and tracks man-made orbital debris**
  - Although some cataloged debris is as small as 5 cm diameter, the nominal size of debris in the catalog is 10 cm in low earth orbit and 1 m at geosynchronous altitudes
  - Catalog currently has approximately 15,000 objects in orbit; 21,500 total tracked
  - Prior to 2007 satellite explosions were the principal source of orbital debris. Now, satellite collisions (intentional and accidental) are the primary source.

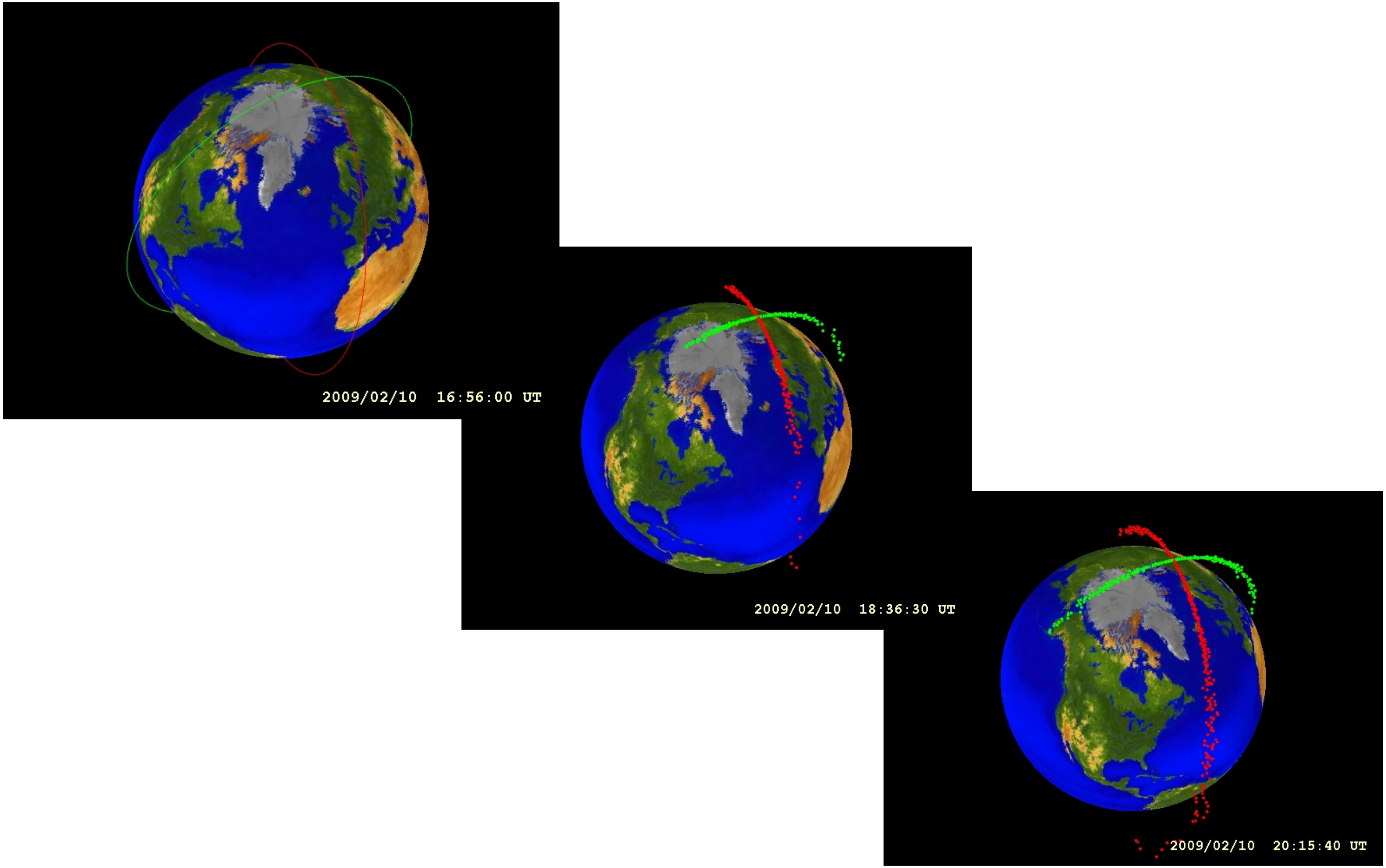


Recent Significant Space Debris Events

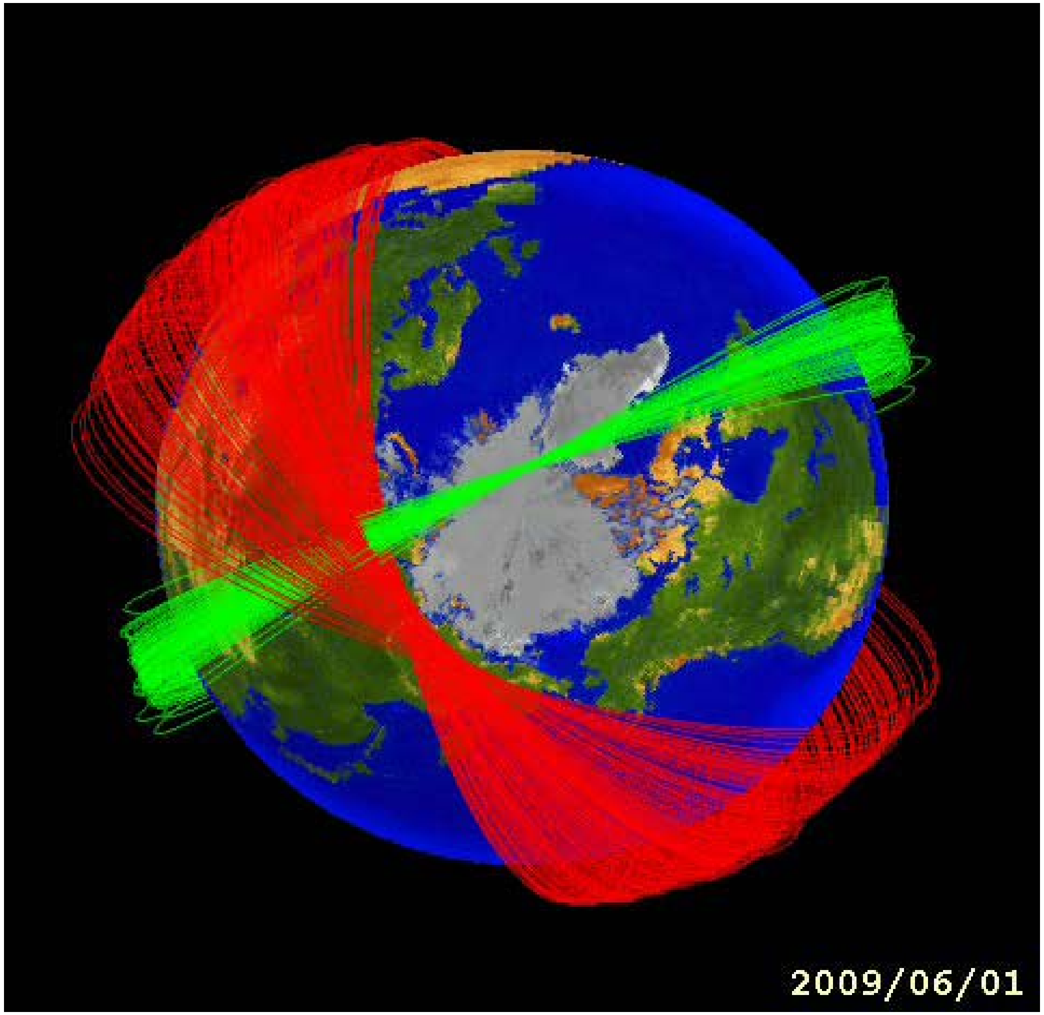
- **Destruction of Fengyun-1C satellite during Chinese anti-satellite test in January 2007 at an altitude of ~850 km.**
  - 2841 cataloged debris by third anniversary of test; >500 additional debris tracked but not yet cataloged.
  - Only 68 cataloged debris have reentered; the majority will have lifetimes of decades.
- **Explosion of Russian Proton upper stage in February 2007 while in highly elliptical orbit of ~500 km by 14700 km.**
  - Estimated 1000 or more debris detected, but less than 100 cataloged to date.
- **Accidental collision of Iridium 33 and Cosmos 2251 in February 2009 at an altitude near 800 km.**
  - More than 1600 cataloged debris to date; Just over 2000 being tracked in orbit.

> 6000 large debris still in orbit from these three events.

Simulation of Debris Clouds

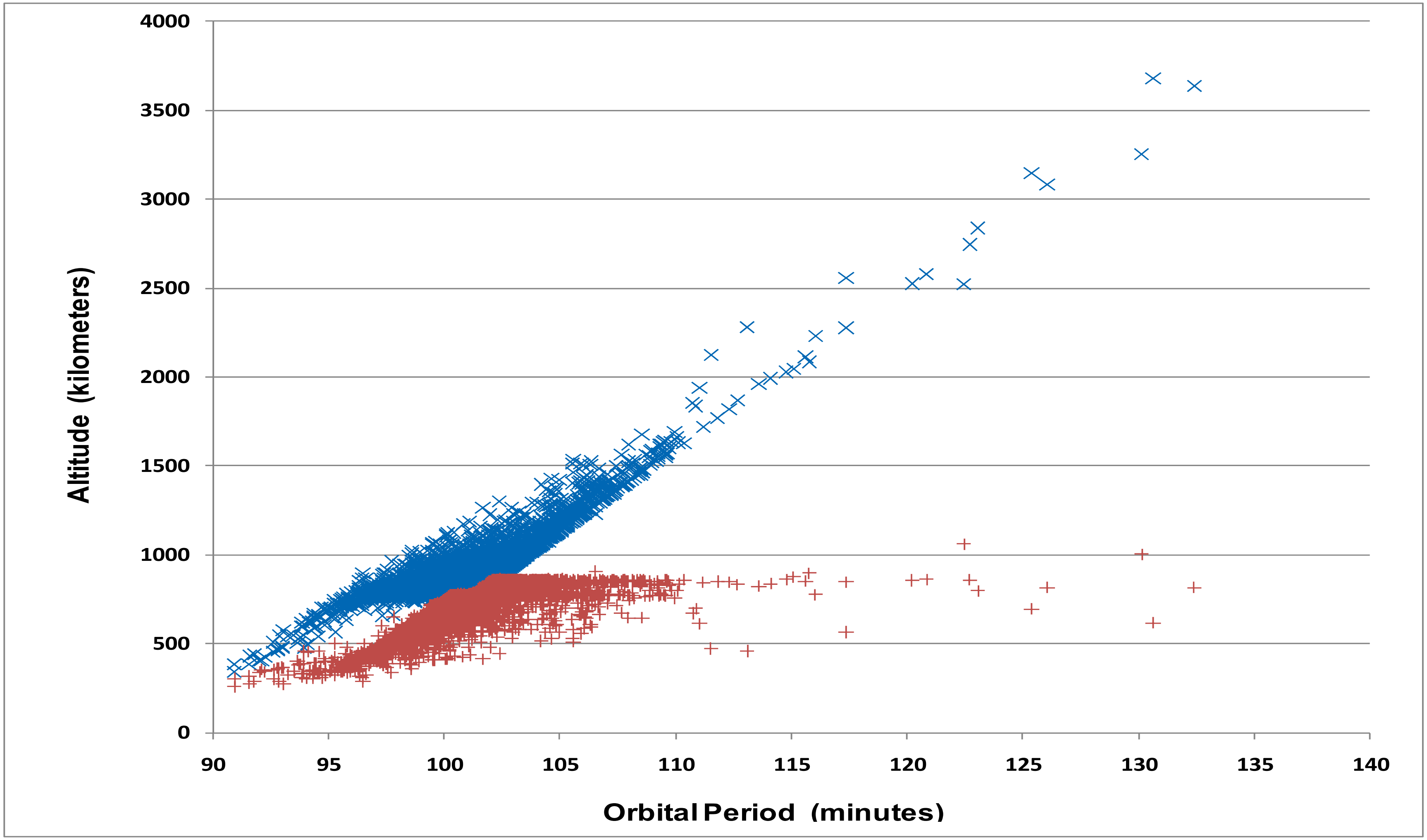


Spread of Debris Orbital Planes

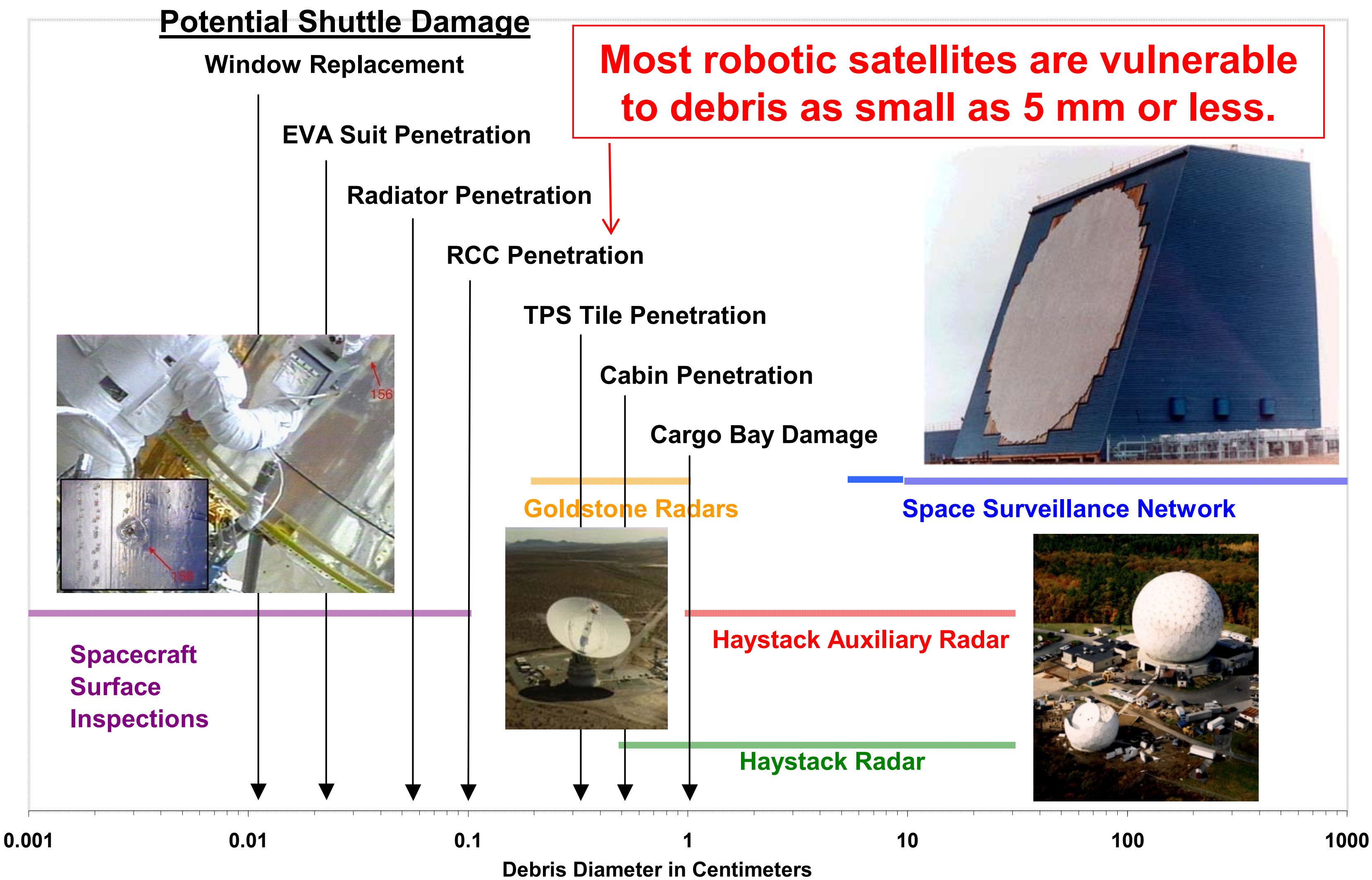


Orbital Debris From Three Major Events

- **Nearly 4200 cataloged debris from Fengyun-1C, Iridium 33, and Cosmos 2251 were spread throughout LEO in January 2010.**



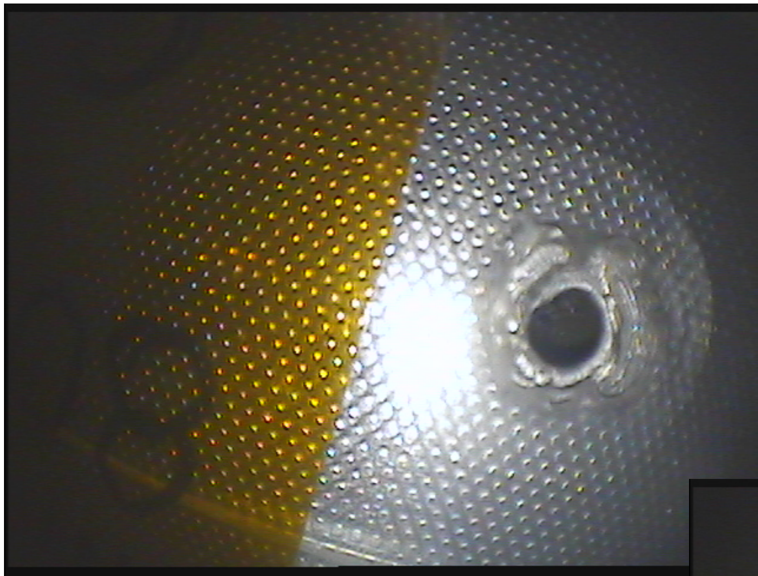
Orbital Debris Detectors and Damage Potential

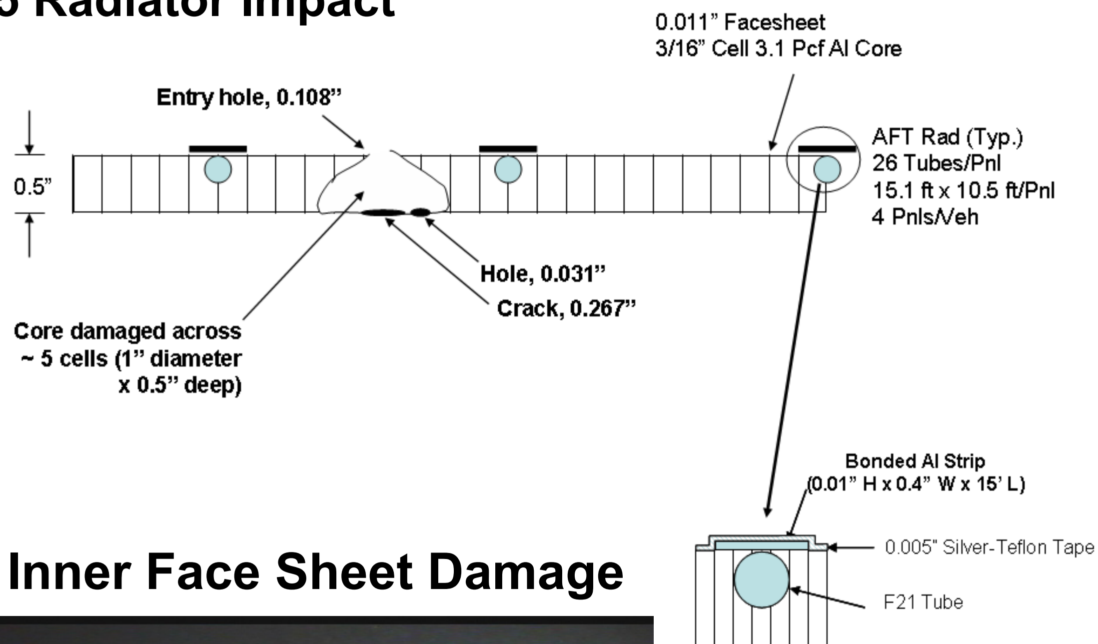


Examination of Returned Surfaces

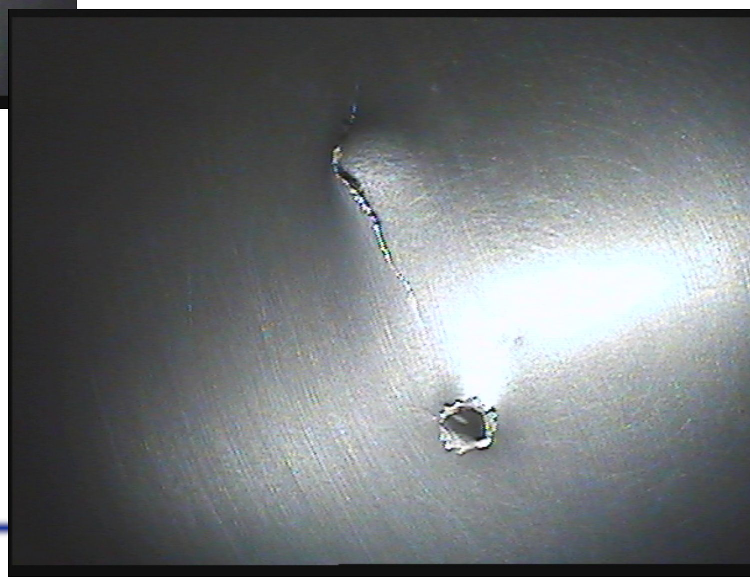
STS-115 Radiator Impact

Outer Face Sheet Damage



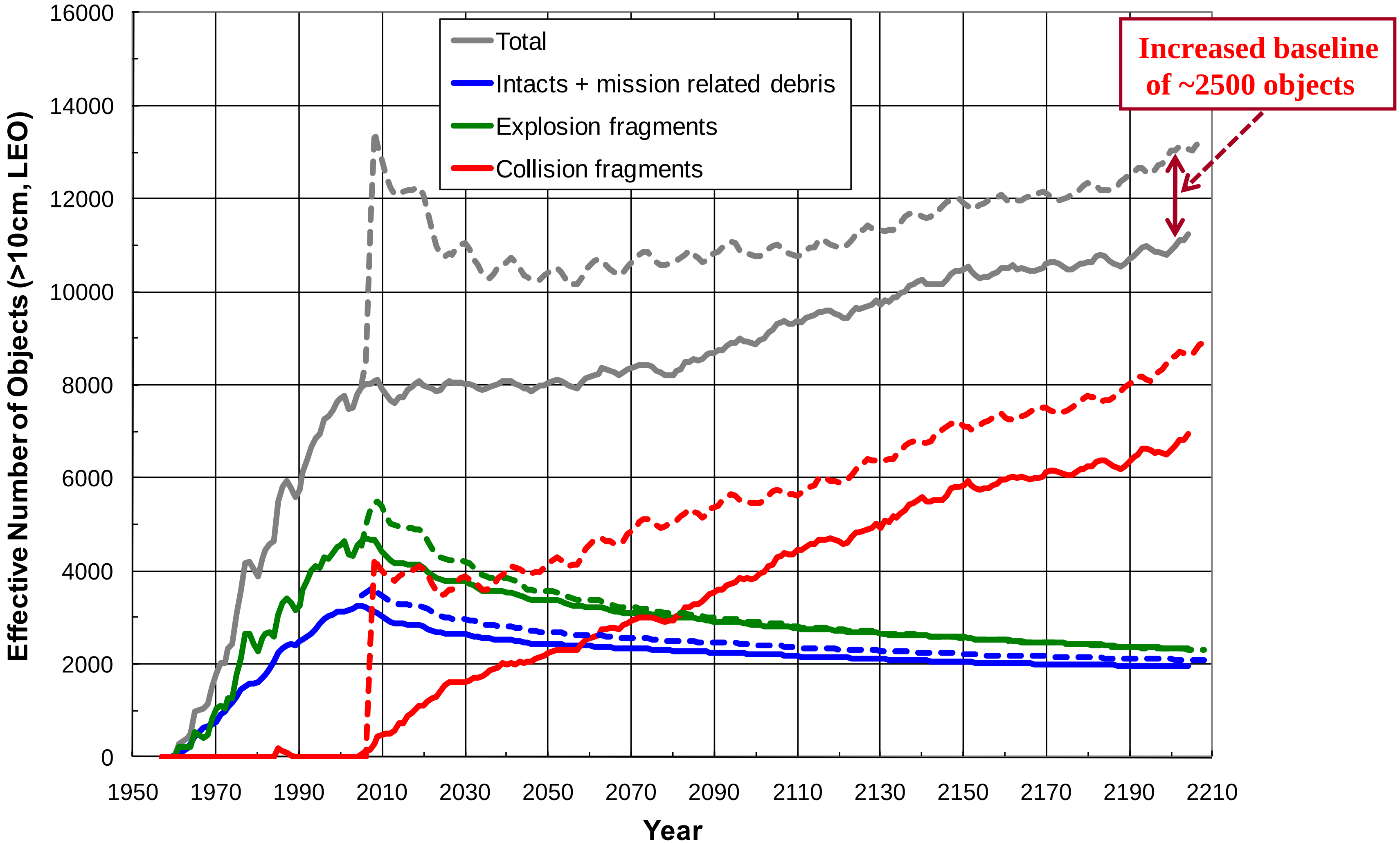


Inner Face Sheet Damage



Estimated impactor size = 1.5 - 2.0 mm

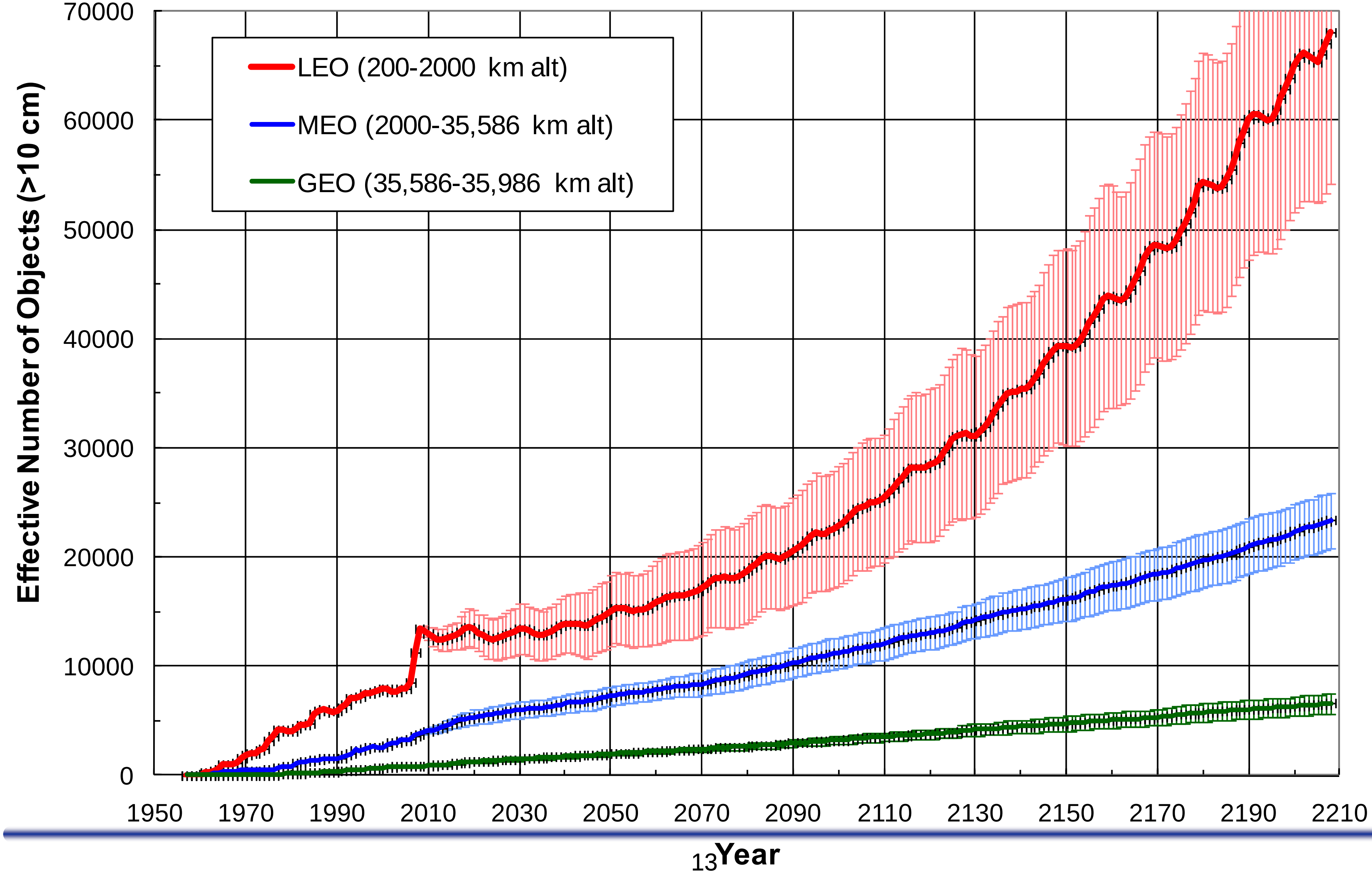
No new Launch Scenario 2005 vs. 2009



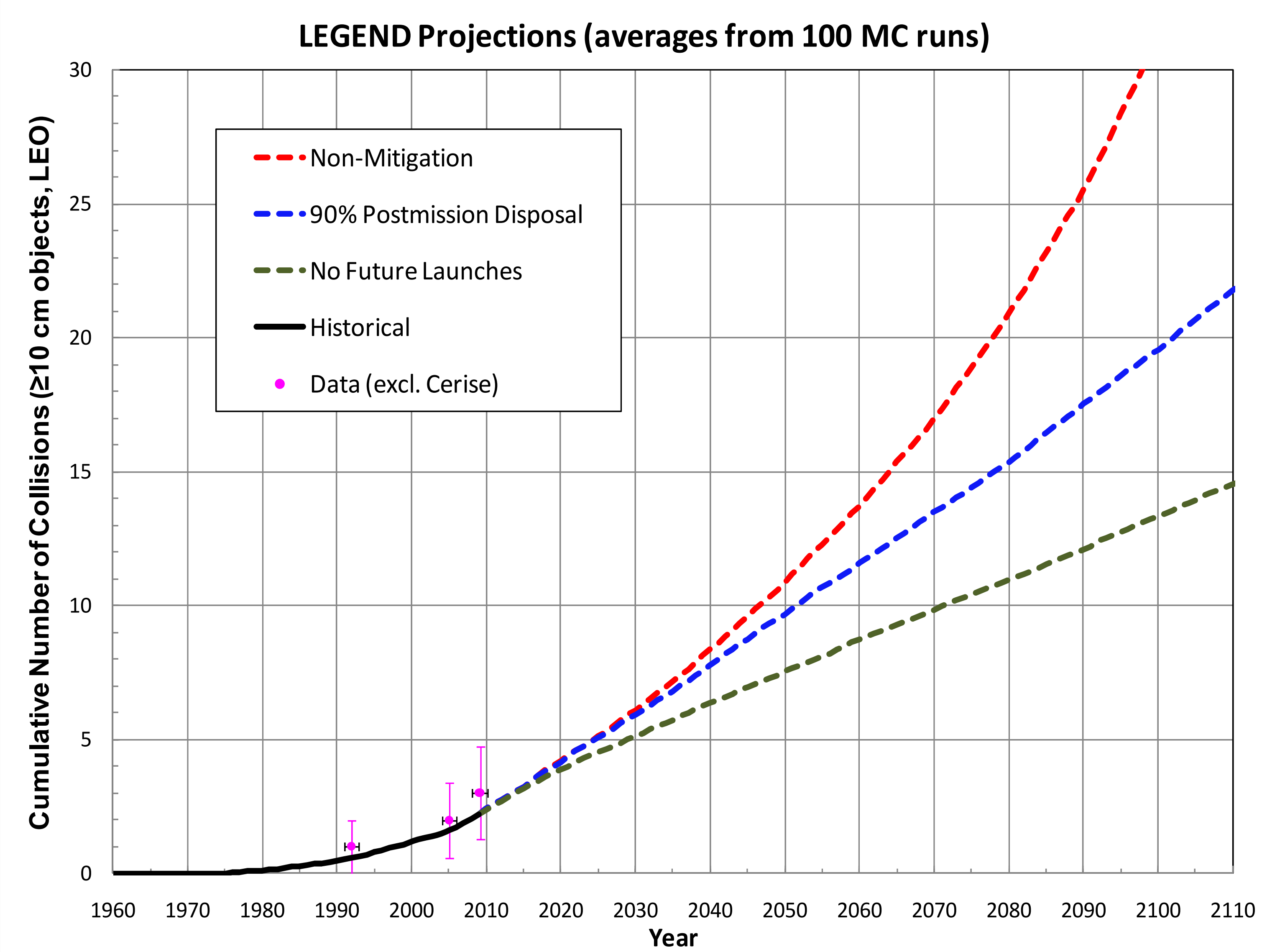
- **Solid lines: 1957-to-2006, no new launches beyond 2006**
- **Dashed lines: 1957-to-2009, no new launches beyond 2009**

Model Results With Launches

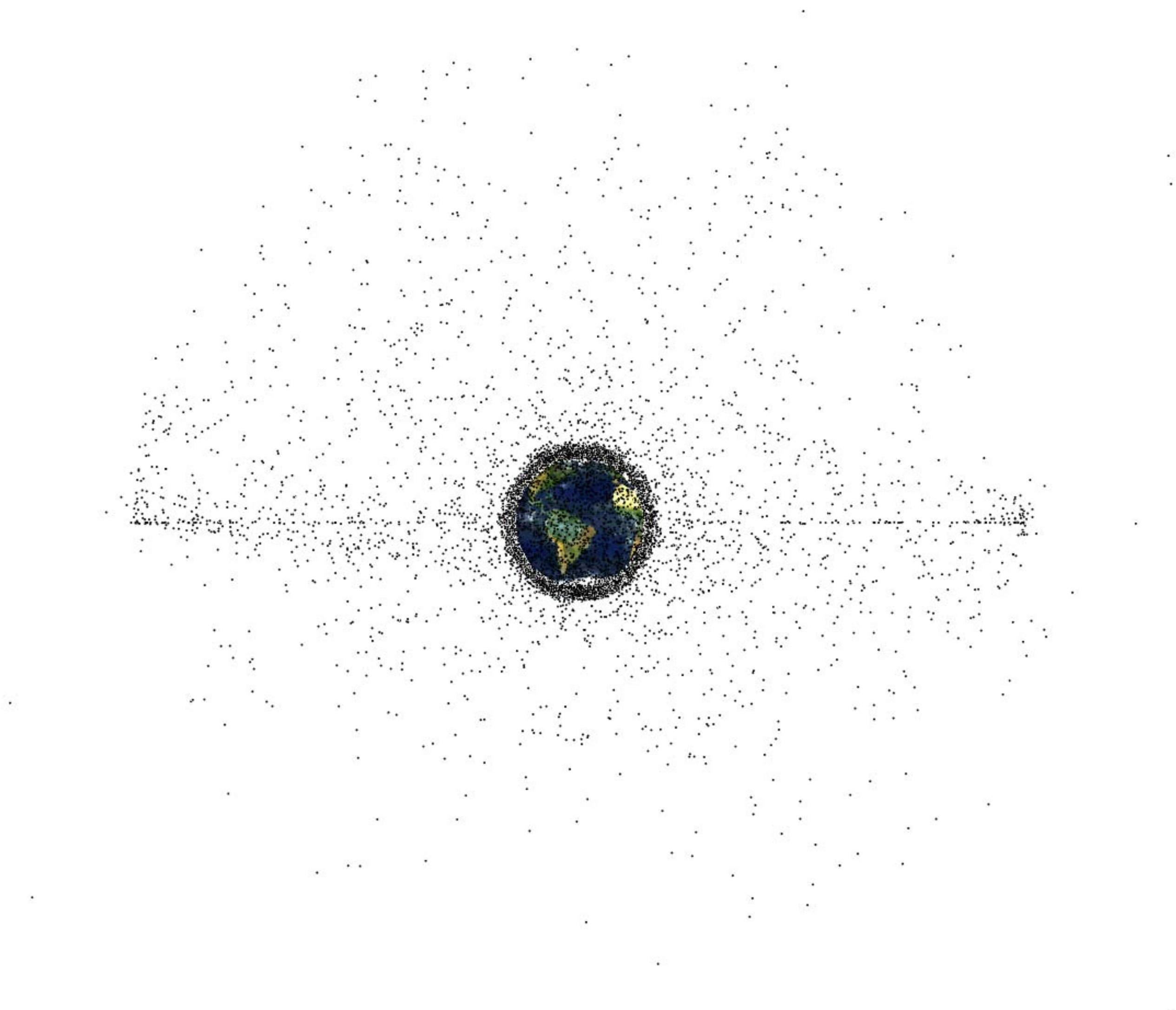
Non-Mitigation Projection (averages and 1-σ from 100 MC runs)



Number of Collisions

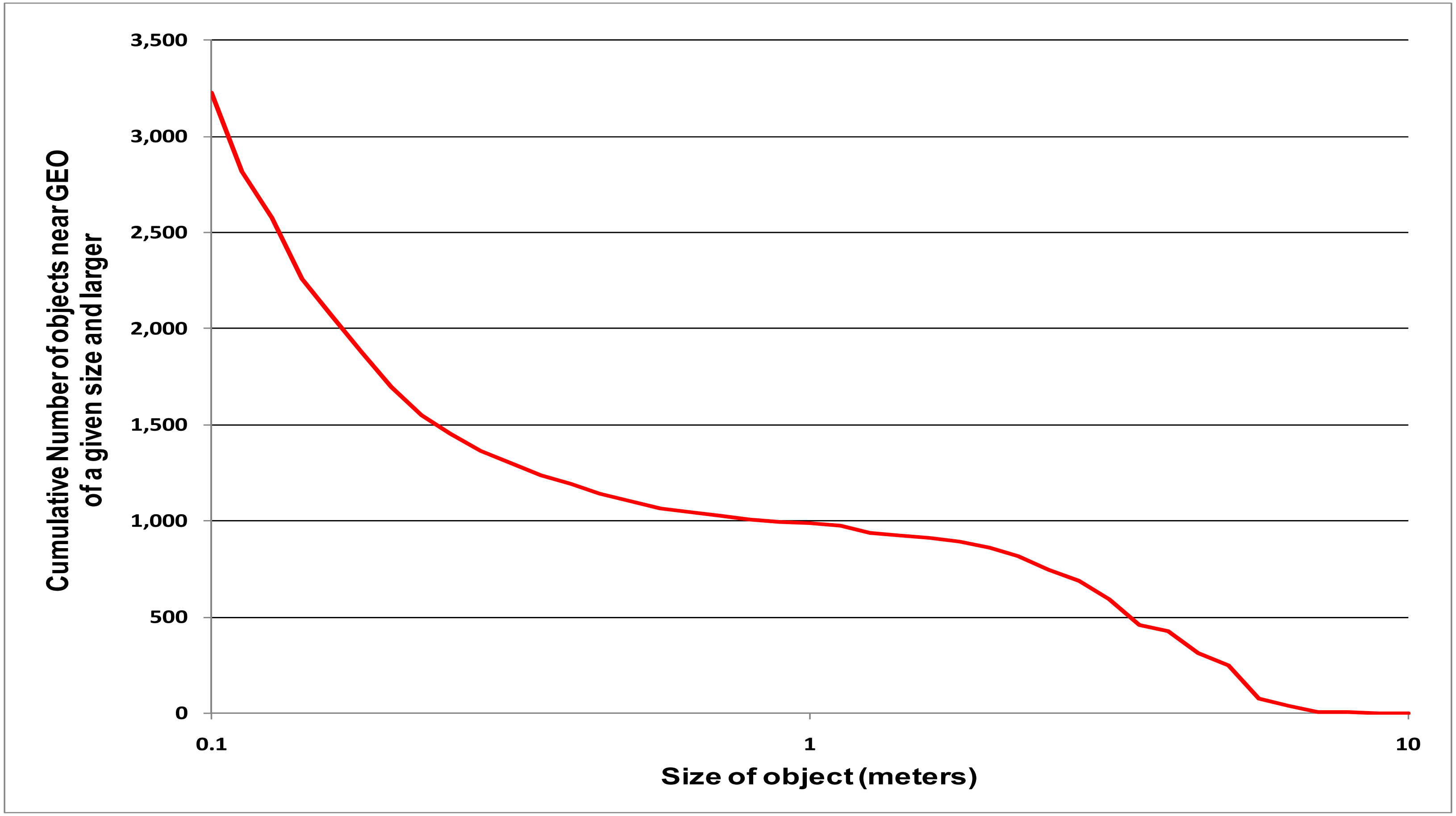


Geosynchronous Altitudes



Population of Objects in GEO

- **During 2000-2009, the number of spacecraft entering GEO exceeded that being removed by more than two to one. New data indicate a significant uncataloged population of sizes between 10 cm and 1 m.**



Summary

- **The threat from orbital debris, although still relatively small, is real and is growing**

- **~95% of the tracked population is non-maneuverable**

- **The tracked population represents less than 1 - 2% of the threat to typical commercial satellites**

- **Sensible Space Traffic Management (given the above)**
  - **Look before you launch**
  - **Perform Collision Avoidance against the tracked population (recognize that this is a small percentage of the risk)**
  - **Follow the US Orbital Debris Mitigation Standard Practices including spacecraft disposal to prevent making the problem worse**

Backup Slides

DEBRIS MITIGATION STANDARD PRACTICES: NORMAL OPERATIONS

OBJECTIVE

1. CONTROL OF DEBRIS RELEASED DURING NORMAL OPERATIONS

Programs and projects will assess and limit the amount of debris released in a planned manner during normal operations.

MITIGATION STANDARD PRACTICES

1-1. *In all operational orbit regimes:* Spacecraft and upper stages should be designed to eliminate or minimize debris released during normal operations. Each instance of planned release of debris larger than 5 mm in any dimension that remains on orbit for more than 25 years should be evaluated and justified on the basis of cost effectiveness and mission requirements.

DEBRIS MITIGATION STANDARD PRACTICES: ACCIDENTAL EXPLOSIONS

OBJECTIVE

2. MINIMIZING DEBRIS GENERATED BY ACCIDENTAL EXPLOSIONS

Programs and projects will assess and limit the probability of accidental explosion during and after completion of mission operations.

MITIGATION STANDARD PRACTICES

2-1. *Limiting the risk to other space systems from accidental explosions during mission operations:* In developing the design of a spacecraft or upper stage, each program, via failure mode and effects analyses or equivalent analyses, should demonstrate either that there is no credible failure mode for accidental explosion, or, if such credible failure modes exist, design or operational procedures will limit the probability of the occurrence of such failure modes.

2-2. *Limiting the risk to other space systems from accidental explosions after completion of mission operations:* All on-board sources of stored energy of a spacecraft or upper stage should be depleted or safed when they are no longer required for mission operations or postmission disposal. Depletion should occur as soon as such an operation does not pose an unacceptable risk to the payload. Propellant depletion burns and compressed gas releases should be designed to minimize the probability of subsequent accidental collision and to minimize the impact of a subsequent accidental explosion.

DEBRIS MITIGATION STANDARD PRACTICES: COLLISIONS

OBJECTIVE

3. SELECTION OF SAFE FLIGHT PROFILE AND OPERATIONAL CONFIGURATION

Programs and projects will assess and limit the probability of operating space systems becoming a source of debris by collisions with man-made objects or meteoroids.

MITIGATION STANDARD PRACTICES

3-1. *Collision with large objects during orbital lifetime:* In developing the design and mission profile for a spacecraft or upper stage, a program will estimate and limit the probability of collision with known objects during orbital lifetime.

3-2. *Collision with small debris during mission operations:* Spacecraft design will consider and, consistent with cost effectiveness, limit the probability that collisions with debris smaller than 1 cm diameter will cause loss of control to prevent post-mission disposal.

3-3. *Tether systems* will be uniquely analyzed for both intact and severed conditions.

DEBRIS MITIGATION STANDARD PRACTICES: DISPOSAL

OBJECTIVE

4. POSTMISSION DISPOSAL OF SPACE STRUCTURES

Programs and projects will plan for, consistent with mission requirements, cost effective disposal procedures for launch vehicle components, upper stages, spacecraft, and other payloads at the end of mission life to minimize impact on future space operations.

MITIGATION STANDARD PRACTICES

4-1. *Disposal for final mission orbits:* A spacecraft or upper stage may be disposed of by one of three methods:

a. Atmospheric reentry option: 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. If drag enhancement devices are to be used to reduce the orbit lifetime, it should be demonstrated that such devices will significantly reduce the area-time product of the system or will not cause spacecraft or large debris to fragment if a collision occurs while the system is decaying from orbit. 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.

b. Maneuvering to a storage orbit: At end of life the structure may be relocated to one of the following storage regimes:

I. Between LEO and MEO: Maneuver to an orbit with perigee altitude above 2000 km and apogee altitude below 19,700 km (500 km below semi-synchronous altitude

II. Between MEO and GEO: Maneuver to an orbit with perigee altitude above 20,700 km and apogee altitude below 35,300 km (approximately 500 km above semi-synchronous altitude and 500 km below synchronous altitude.)

III. Above GEO: Maneuver to an orbit with perigee altitude above 36,100 km (approximately 300 km above synchronous altitude)

IV. Heliocentric, Earth-escape: Maneuver to remove the structure from Earth orbit, into a heliocentric orbit.

Because of fuel gauging uncertainties near the end of mission, a program should use a maneuver strategy that reduces the risk of leaving the structure near an operational orbit regime.

c. Direct retrieval: Retrieve the structure and remove it from orbit as soon as practical after completion of mission.

4-2. *Tether systems* will be uniquely analyzed for both intact and severed conditions when performing trade-offs between alternative disposal strategies.