Space Debris Research in Shanghai Institute of Satellite Engineering

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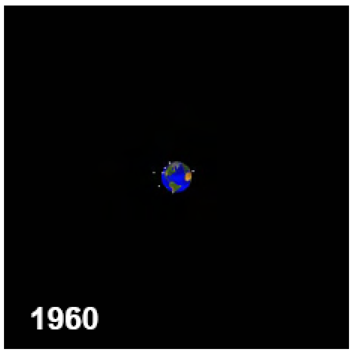
October 2011

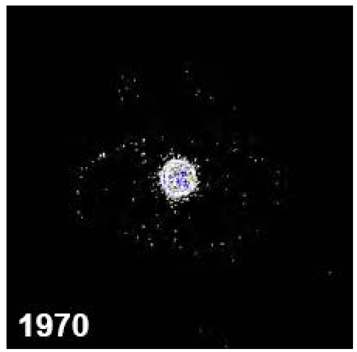
Outline

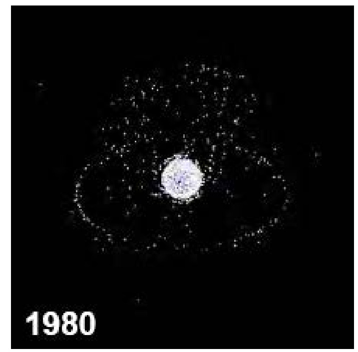
- The Orbital Debris Environment
- Lifecycle Space Debris Mitigation Design
- Reorbit Tests of GEO Satellites
- Active Orbital Debris Removals
- Active Avoidance Maneuvers
- Conclusions

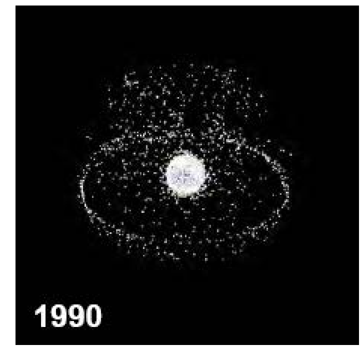
The Orbital Debris Environment

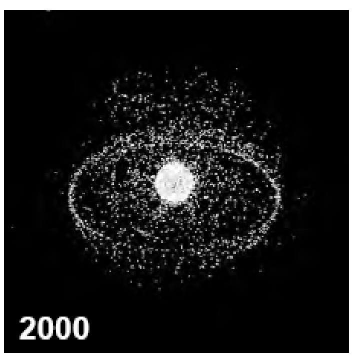
➢ Growth of the Satellite Population

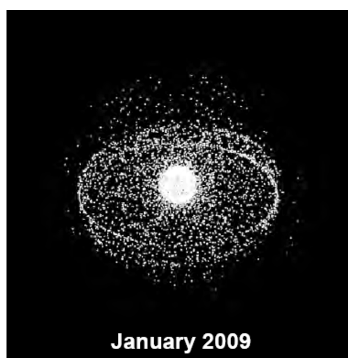












✓ **Over 16,000 objects (>10cm in diameter) tracked by U.S. Space Surveillance Network in 2011**

The Orbital Debris Environment

➢ Threatens of Space Debris

✓ Increasing Probability of Collisions

- collision happened between Irdium Satellite and Cosmos satellite in 2009

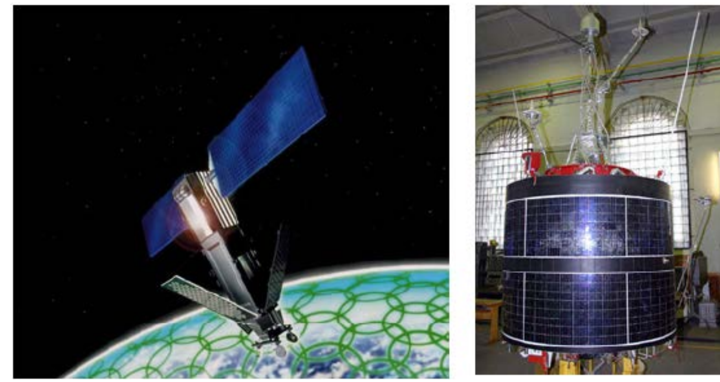


Figure 1 Configurations of an Irdium satellite (left) and one Cosmos satellite (right)

✓ Potential Damage on Human Beings on Earth

- the reenter event of the U.S.'s satellite (UARS) has already triggered the panic around the world in 2011

Figure 2 Configurations of an UARS satellite

Lifecycle Space Debris Mitigation Design

The space debris mitigation measures of GEO satellites are focus on the following four areas:

✓ Limitation of debris of the GEO satellites during normal operations;

✓ Minimization of the potential for on-orbit break-ups;

✓ Post-mission disposal;

✓ Prevention of on-orbit collisions.

Lifecycle Space Debris Mitigation Design

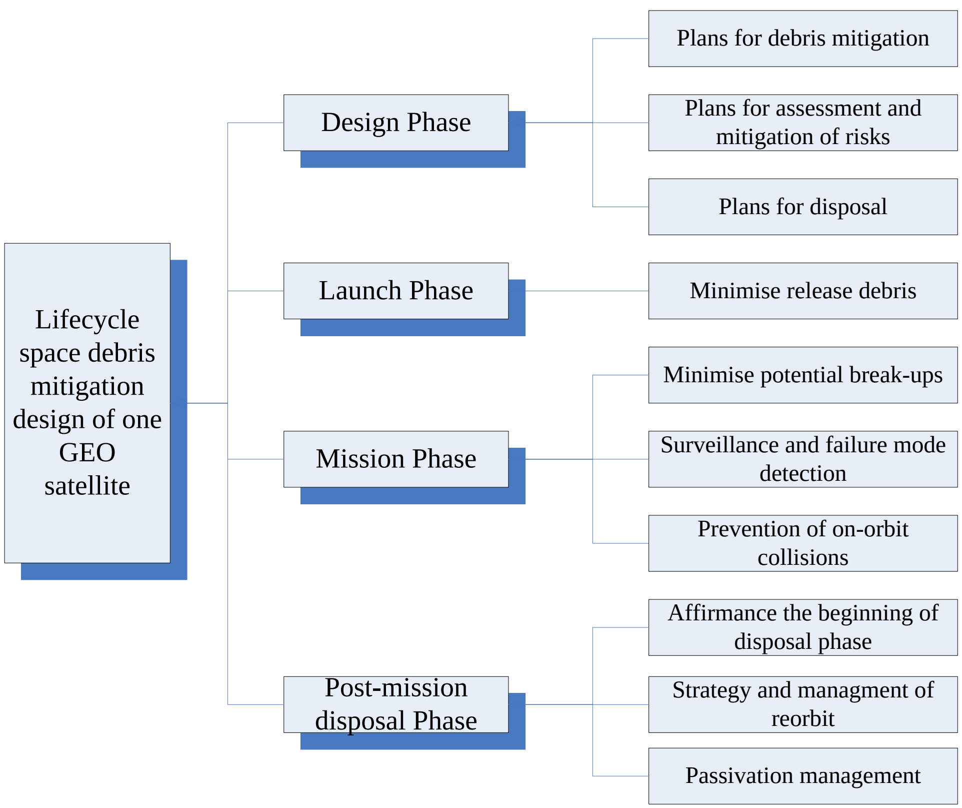


Figure 3 Lifecycle space debris mitigation design of one GEO satellite

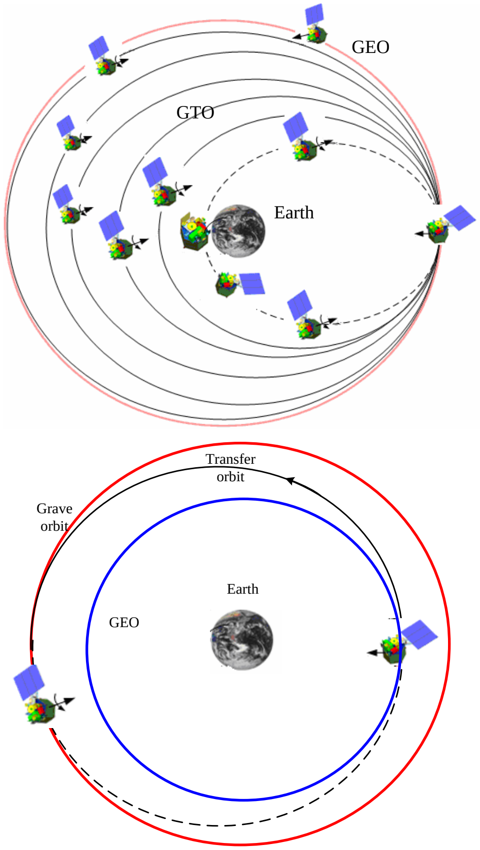


Figure 4 Launch phase and post-mission disposal phase of one GEO satellite

Reorbit Tests of GEO Satellites

The Reorbit Test of one GEO Weather Satellite is Implemented in 2006;

During the reorbit test:

- ✓ the cumulative operation numbers of the satellite's control system is over 1,800 times;
- ✓ the vessels' pressure dropped below 1.7 MPa;
- ✓ the remaining fuel is exhausted.

At the end of the reorbit test:

- ✓ the anchor point of this satellite is 90.72 degrees east longitude;
- ✓ the satellite drifts west by the rate of 0.75 degrees per day

Figure 5 Configurations of one GEO weather satellite

Reorbit Tests of GEO Satellites

The Other Reorbit Test of one GEO Weather Satellite is Implemented in 2007;

- ✓ In accordance with the IADC Space Debris Mitigation Guidelines
- ✓ Based on the disposal of experience of the former GEO weather satellite.

At the end of the reorbit test:

- ✓ The perigee altitude and apogee altitude of the orbit of this GEO satellite are more 800 km and 1,650 km higher than the nominal elevation.

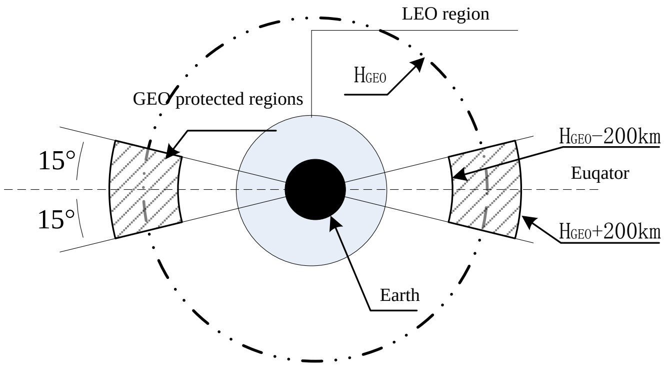


Figure 6 GEO protected regions

Active Orbital Debris Removals

Table 1 Survey of solutions for active orbital debris removals

	LEO			GEO
Debris size	＜1cm	1 to 10cm	Large (derelict spacecraft or expended rocket bodies)	Large (derelict spacecraft or expended rocket bodies)
Number of objects	Millions	150,000 objects in LEO	over 16,000(＞10cm)	Hundreds
Potential options	space-based magnetic field generator	space based laser	magnetic sail	solar sail
	/	airborne based laser	momentum tethers	momentum tethers
		ground based laser (Orion)	drag augmentation device	capture/orbital transfer vehicle
	/	/	electrodynamic tethers	attachable propulsive module
	/	/	attachable prop module or OTV	/
Systems with most potential	no practical solutions	Ground based lasers studied by MSFC in 1990s show promise. Advances in pico pulsed lasers may bring desirable effects. All 1-10cm debris under 1500 km in altitude could be removed in approx 3-5 years with one facility located near the equator.	Either a electrodynamic tether or a large device must be attached to the large spacecraft via drawback to tethers is the reentry point is not controllable whereas a propulsive deorbit module allows precision guidance upon disposal. Decay times with tethers go from 325 yrs at an 800 km orbit to 200 days.	GEO space junk needs to be put into a disposal or graveyard orbit at least 300 km greater in altitude than GEO. A space based vehicle stationed at GEO seems to offer the best solution. AR&D or Capture is needs. Propulsion options between storable or ion system driving design factor.

Active Orbital Debris Removals

Advantages of tether technology:

- ✓ non-polluting;
- ✓ Lower energy requirements;
- ✓ Lower accuracy requirements;
- ✓ Flexible and reliable.

Capture types suited for tether technology:

- ✓ Network structure;
- ✓ Clutch mechanism;
- ✓ Electromagnet;
- ✓ Cone / cone cover;
- ✓ Combination of capture mechanism.

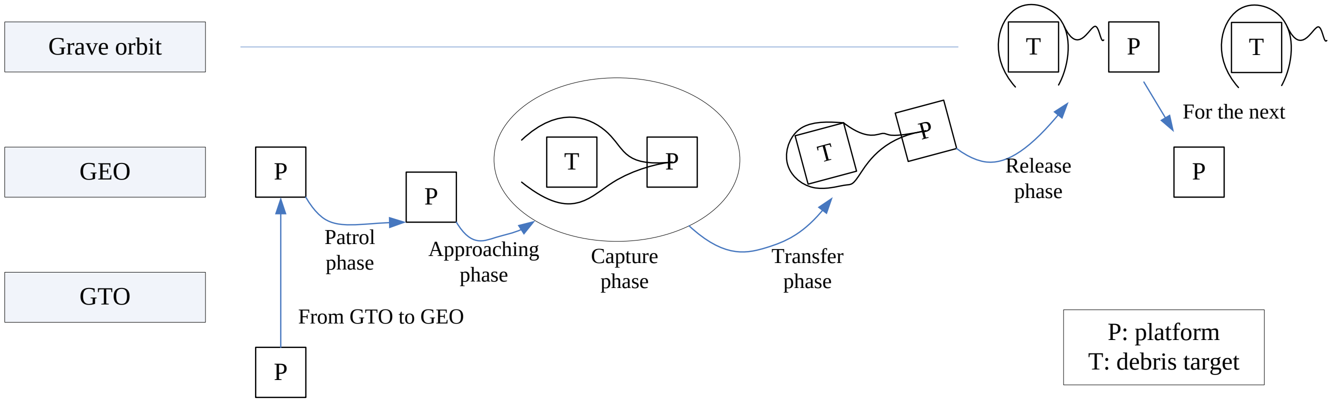


Figure 7 Procedure of tether assisted removal system

Active Avoidance Maneuvers

✓ In 2009, there was a uncertainty space debris would approach to one satellite on October 3 and the shortest distance might be only 160 m;

✓ First of all, the status of the satellite was confirmed within the ability of the domestic monitoring stations;

✓ Then the data packs were injected to altitude the satellite orbit height;

✓ On October 3, data showed that the altitude error was less than 4 m, the eccentricity error was less than three hundred thousandths, and the collision probability declined to 10^{-7}.

Conclusions

Shanghai Institute of Satellite Engineering have made great breakthrough about debris mitigation in the following aspects:

- ✓ lifecycle space debris mitigation design of GEO satellites;
- ✓ reorbit technology of abandoned GEO satellites;
- ✓ active orbital debris removals;
- ✓ active avoidance technology.

Thanks！