BEIHANG UNIVERSITY

INVESTIGATION OF SPACE DEBRIS REMOVAL USING TETHER DEORBIT METHOD

Sun Liang, Chen Shenyan

SCHOOL OF ASTRONAUTICS, BEIHANG UNIVERSITY

OUTLINE

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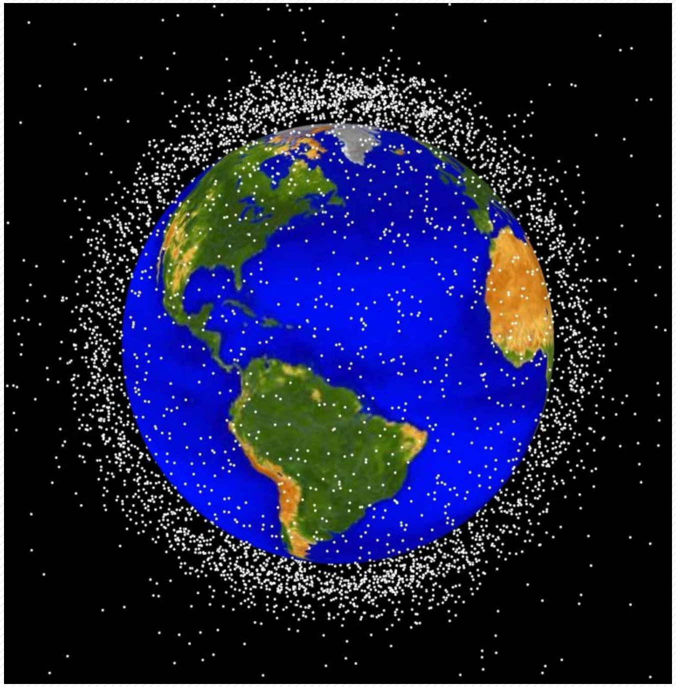
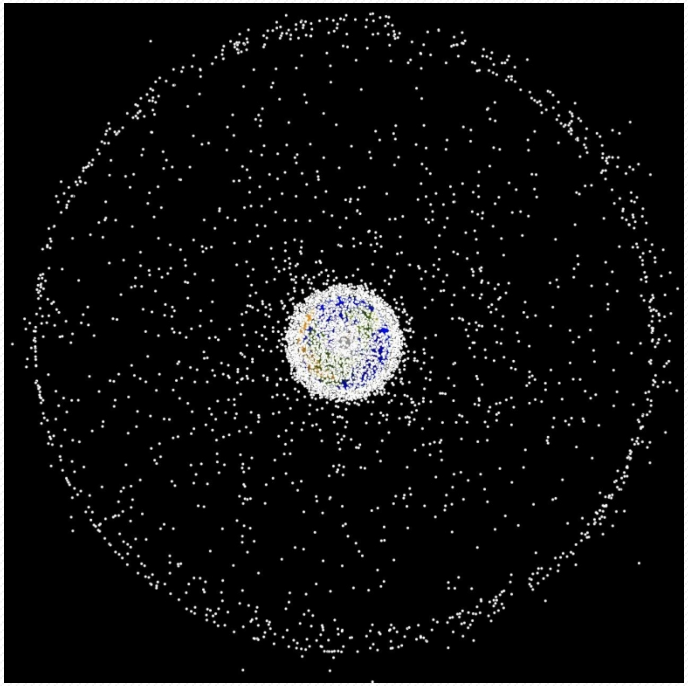
INTRODUCTION TO SPACE DEBRIS



Distribution of space debris (LEO region)



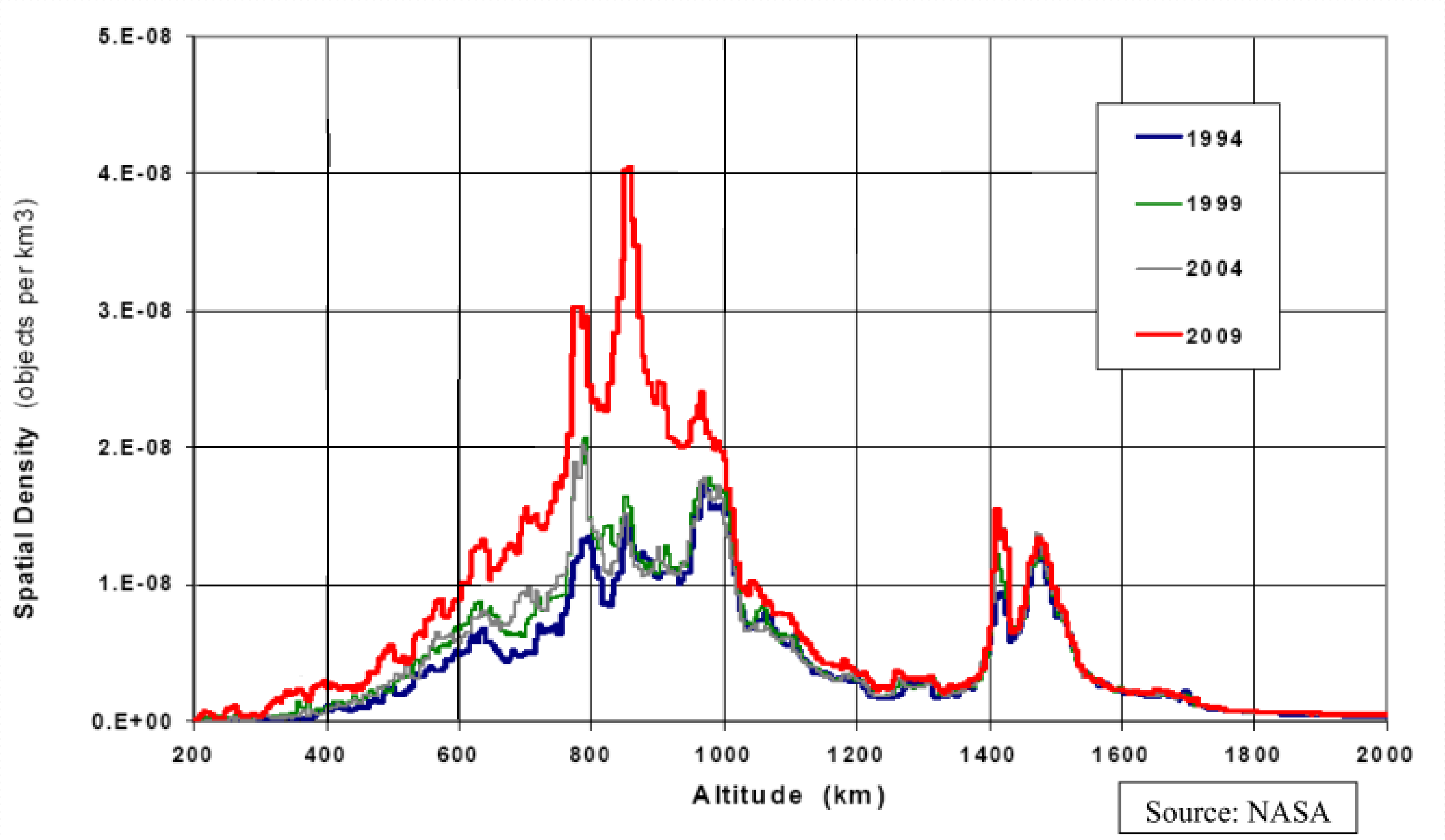
Distribution of space debris (Global view)

INTRODUCTION TO SPACE DEBRIS

Categories of LEO Debris

Physical Size	Comments	Potential Risk to Satellites
> 10 cm	Can be tracked No effective shielding	Complete destruction
1-10 cm	Larger objects in this range may be tracked No effective shielding	Severe damage or complete destruction
< 1cm	Cannot be tracked Effective shielding exists	Damage

INTRODUCTION TO SPACE DEBRIS



Graphic evolution of total trackable LEO object population since 1994

INTRODUCTION TO SPACE DEBRIS

Debris Events

Name	Year	Altitude	Cataloged Debris	Cause
Cosmos 2251	2009	790 km	1267	Accidental collision
Iridium 33	2009	790 km	521	Accidental collision
Cosmos 2421	2008	410 km	509	Unknown

Collision of Iridium33 & Cosmos2251

A commercial communications satellite (IRIDIUM 33) and a defunct Russian satellite (COSMOS 2251) impacted each other on February 9th, 2009 above Northern Siberia, creating a cloud of debris.

ACTIVE DEBRIS REMOVAL TECHNIQUES

Deorbit
to atmosphere

	Size < 1cm		Size 1-10cm	Size > 10cm	
	metal	other		cooperating	tumbling
Orbit LEO	Magnetic Field gen.		Ground/Air/Space based Laser Foams Thruster exhaust	Ret. Surf. Tethers Magnetic sail Prop. Module Tentacles	Net Tentacles
	Retarding surface Sweeping surface Space based Laser Foams Thruster exhaust				
Orbit GEO	Foams Thruster exhaust [trackability is difficult]			Capture Vehicle Momentum Tether Solar sail	Net Tentacles

graveyard

sub-system damages → Catastrophic damages

Source: J. Olympio, presentation at CNES Orbital Debris Removal Workshop, Paris, 22 June, 2010

ACTIVE DEBRIS REMOVAL TECHNIQUES

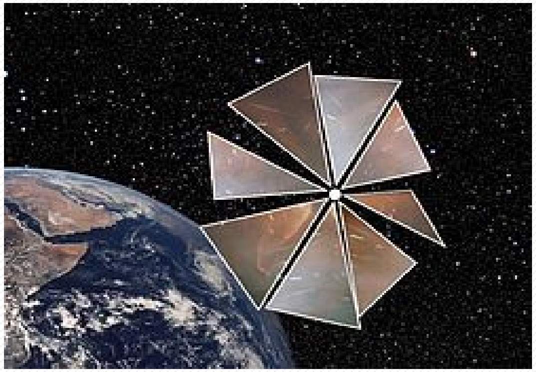
Briefly discuss

Solar sail

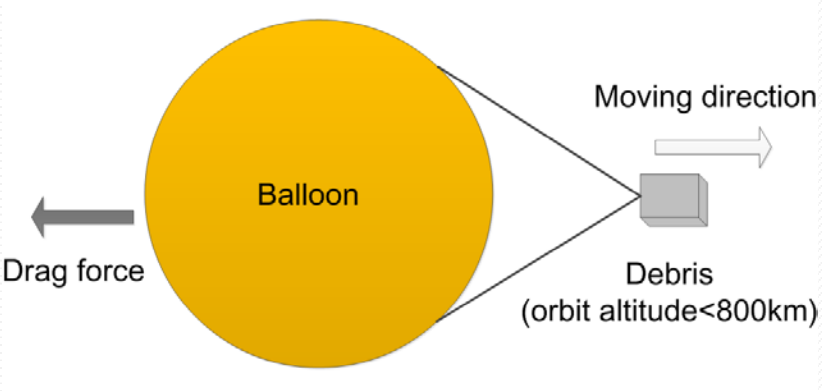
◆An option for disposal of objects in high orbits

◆No propellant storage or engines required

◆Hard for deployment and control



Source: http://en.wikipedia.org/wiki/Solar_sail



Drag augmentation device

◆Effect of atmospheric drag on satellite increased

◆Effective area increased without increasing mass

◆Orbital lifetime reduced from years to weeks

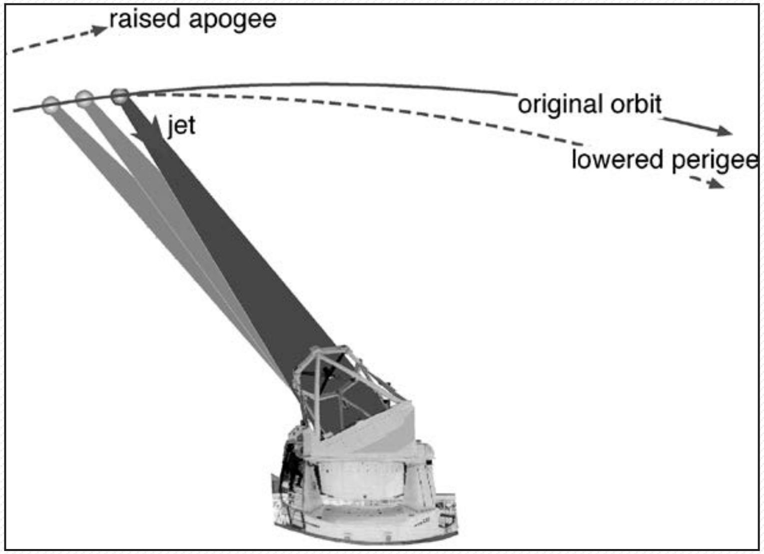
ACTIVE DEBRIS REMOVAL TECHNIQUES

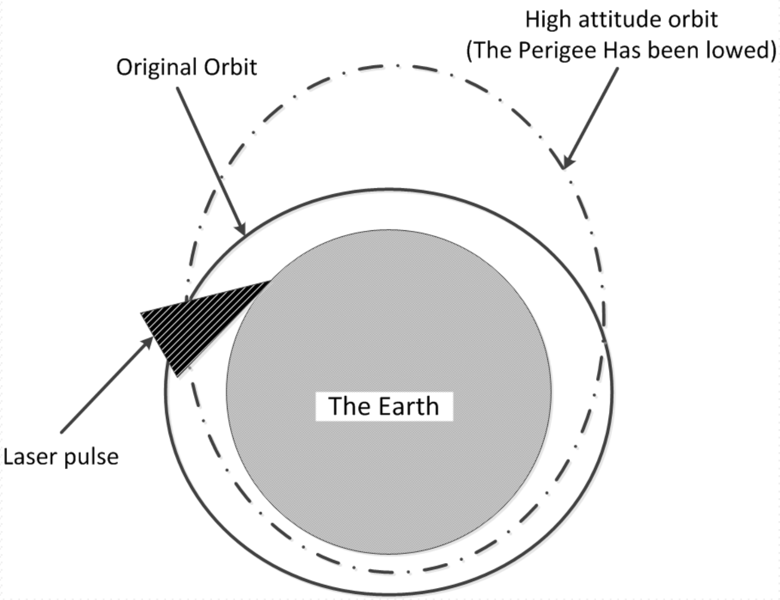
Laser

◆A feasible way to remove 1~10cm debris from LEO

◆Burning: make use of laser beam to heat debris and make it sublimated

◆Promoting: irradiate debris and blow off a plasma



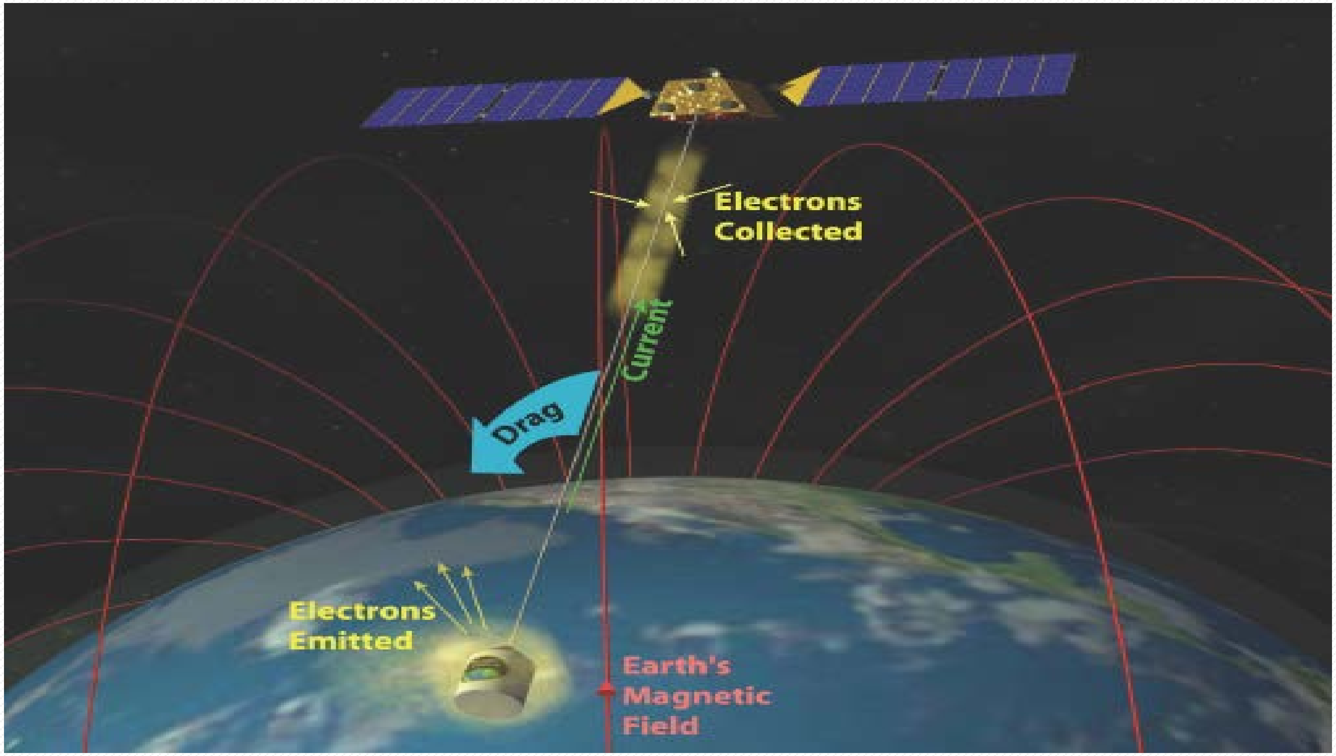


Source: Phipps et al., J. Propulsion, 26:4(2010)

COMPARISON OF TETHER DEORBIT METHODS

Electrodynamic tether

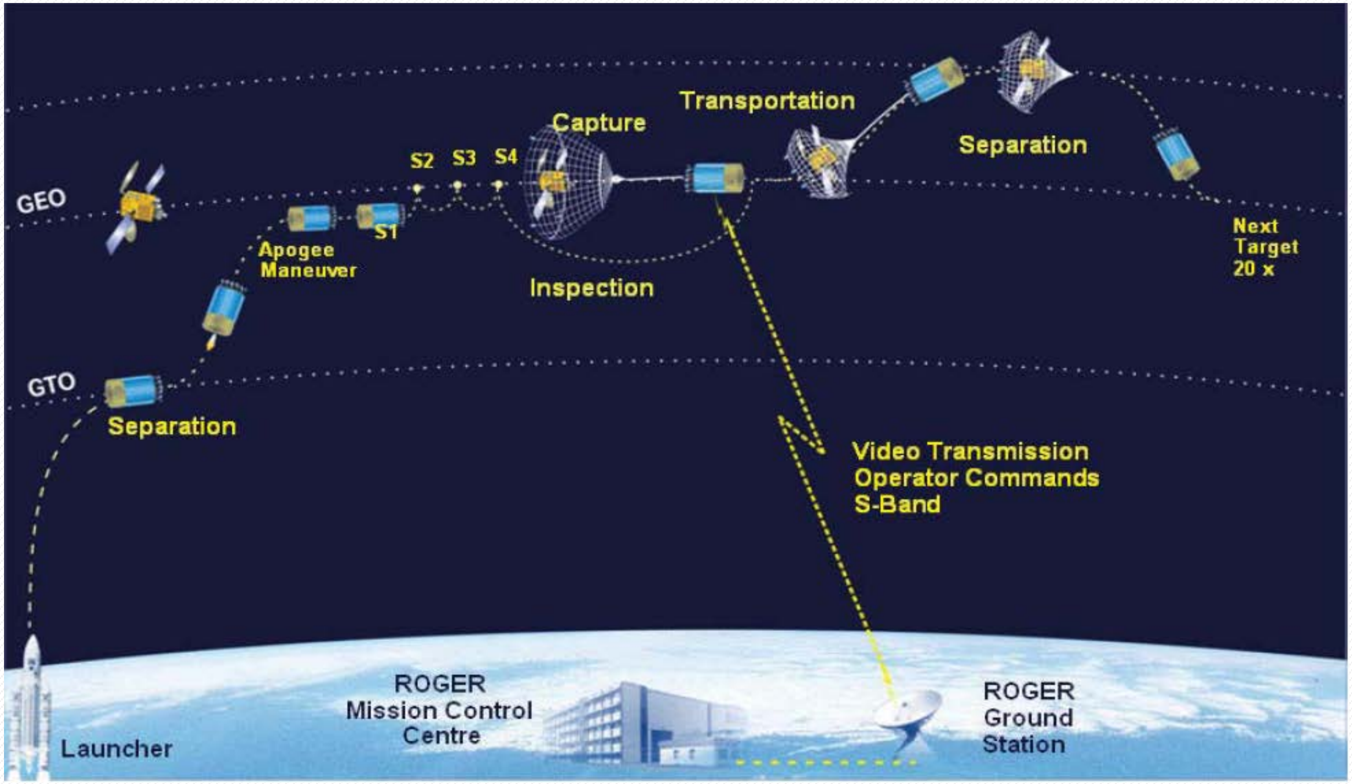
- A good way to de-orbit the LEO debris
- Based on the exploitation of the Lorenz force



COMPARISON OF TETHER DEORBIT METHODS

Tether drag deorbit

- To approach and capture an abandoned satellite in GEO region
- To tow it into a graveyard orbit



COMPARISON OF TETHER DEORBIT METHODS

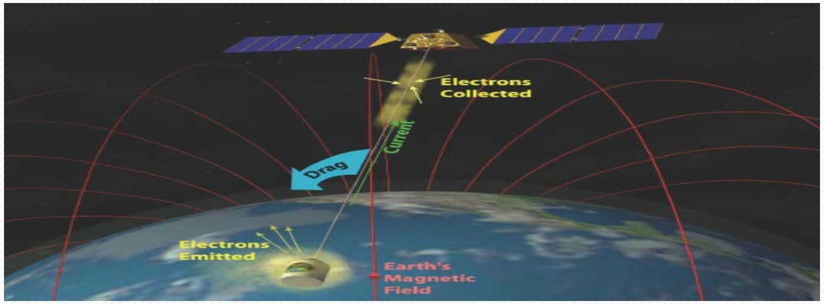
Projects

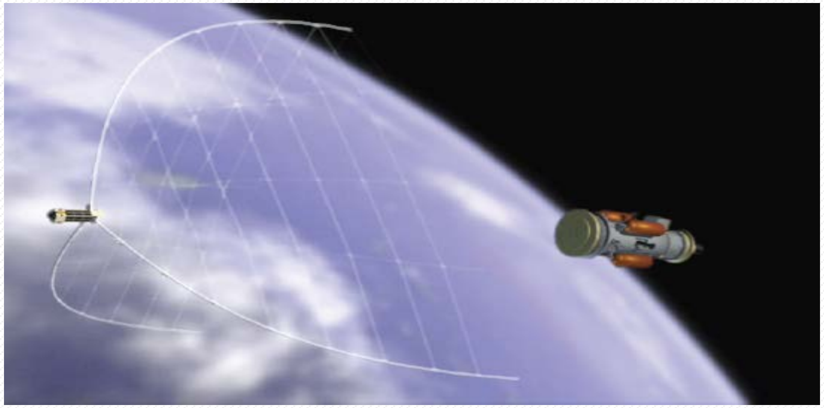
Electrodynamic tether:

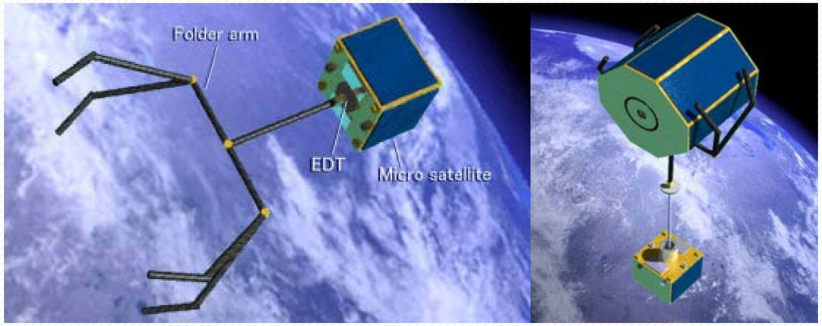
1. TSS-1\ TSS-1R (ASI&NASA)
   (Tethered satellite system)

2. GRASP (TUI)
   (Grapple, Retrieve, & Secure Payload)

3. SDMR (JAXA)
   (Space Debris Micro Remover)







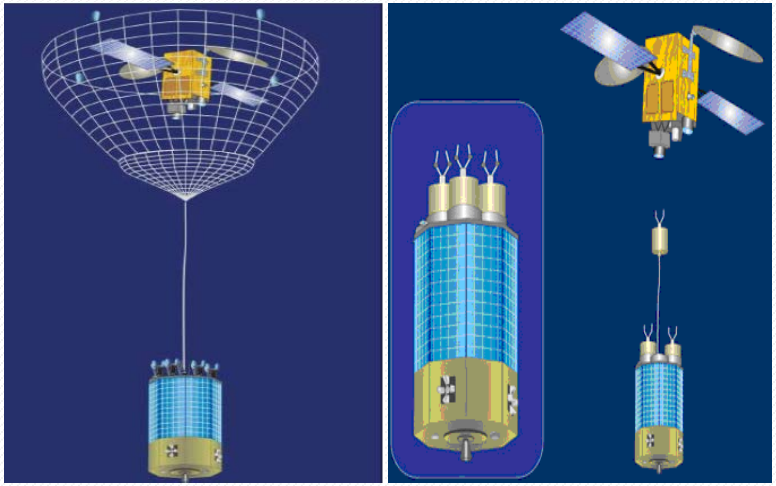
COMPARISON OF TETHER DEORBIT METHODS

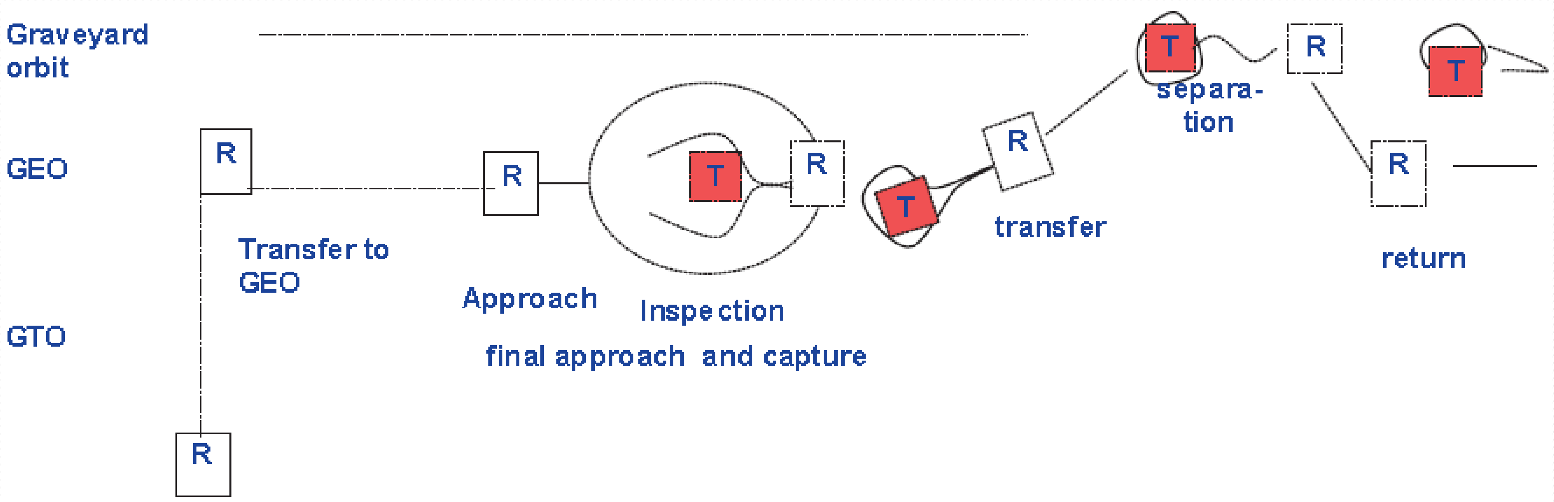
Projects

Tether drag deorbit:

1. ROGER
   (Robotic Geostationary Orbit Restorer)

2. Space tug missions





COMPARISON OF TETHER DEORBIT METHODS

Attainable range

Electrodynamic tether: LEO   Tether drag deorbit: LEO/GEO

Time consuming

Terminator Tether：7.5km tether, 1% of the host spacecraft's mass

Inclination (deg)	Orbital altitude (km)	Deorbit time (day)
0	**400**	**10**
0	**900**	**55**
0	**1400**	**170**
25	**1400**	**220**
50	**1400**	**325**
75	**1400**	**poor effective**

COMPARISON OF TETHER DEORBIT METHODS

Projects costs

Electrodynamic tether:

$ 100,000 per flight unit (Terminator Tape)

Tether drag deorbit:

1. $20 million per grave yard mission
& $2 million per inspection (ROGER)

2. $20.48 million for satellite deorbiting
& $15 million for each piece (Space tug mission)

COMPARISON OF TETHER DEORBIT METHODS

Reliability

Electrodynamic tether:

1. The possibility of tether breaking by debris is augmented
2. Tether material makes a great influence on reliability

Tether drag deorbit:

1. The magnitude of tether tension might lead to the tether breaking
2. The phenomena of tether twining may occur

CHANLLENGES IN TETHER DEORBIT METHODS

- Solution of many technical challenges
- Political, legal, economic and cultural
- International cooperation

THANKS!