SPACE DEBRIS AND PRESENT ACTIVE DEBRIS REMOVAL TECHNIQUES

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OUTLINE

The presentation mainly states the present space debris situation and discusses the active debris removal techniques.

INTRODUCTION TO SPACE DEBRIS

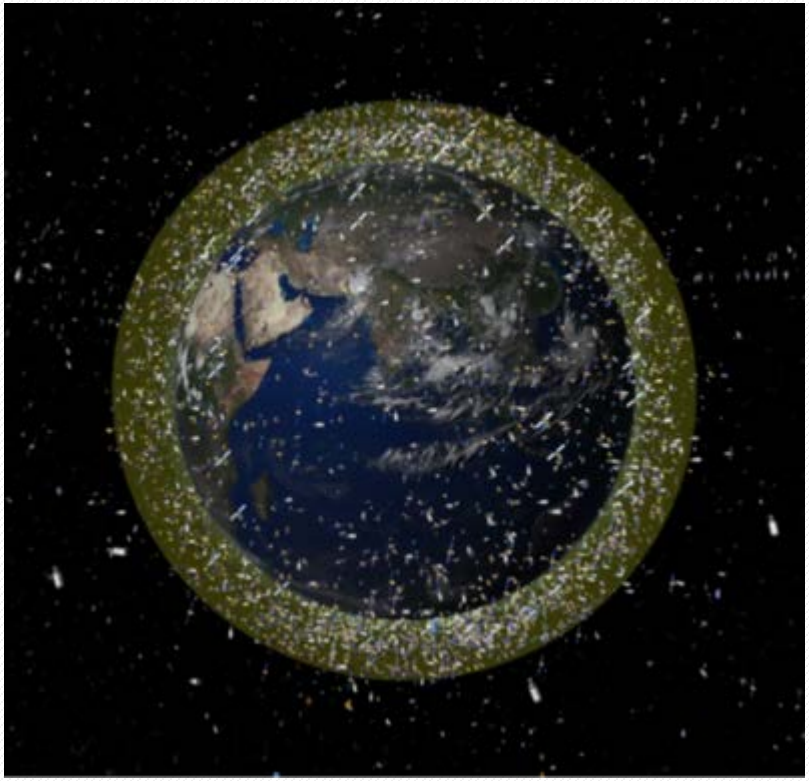
ACTIVE DEBRIS REMOVAL CONCEPT

ACTIVE DEBRIS REMOVAL TECHNIQUES

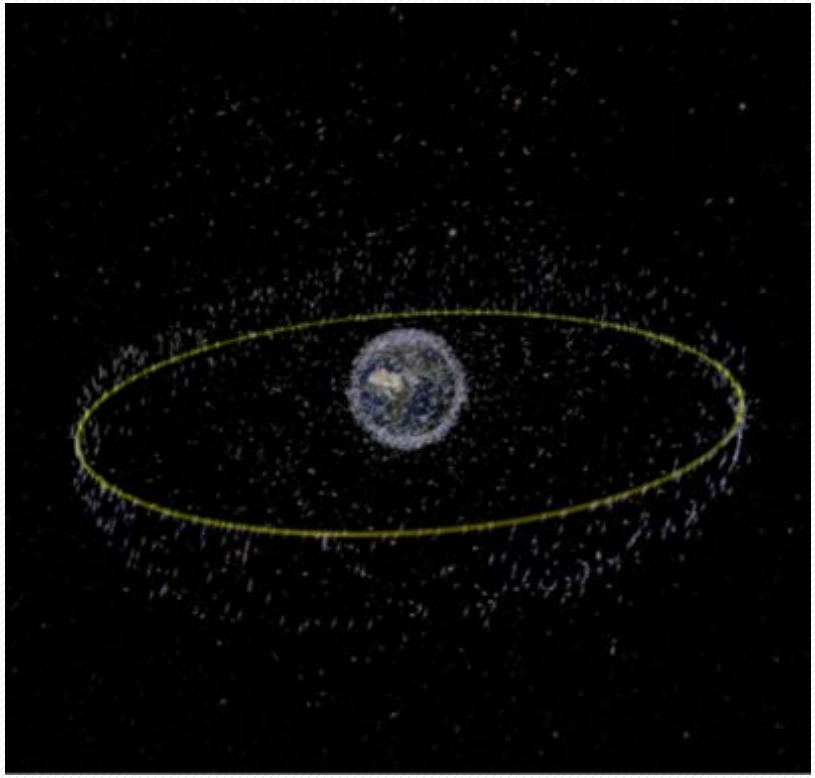
CHALLENGES IN INSTITUTING EFFECTIVE SPACE DEBRIS REMOVAL

INTRODUCTION TO SPACE DEBRIS

Space environment became unsafe by numerous debris produced during human space activities.



Distribution of catalogued objects in space - close-up of the LEO region.
Credits: ESA



Distribution of catalogued objects in space - global view.
Credits: ESA

Source: http://www.esa.int/esaMI/Space_Debris/SEMQQ8VPXPF_1.html#subhead5

INTRODUCTION TO SPACE DEBRIS

The source of space debris could be expired satellites, spent rocket upper stages, fragments from explosions and collisions, paint flakes, chunks of slag from solid rocket motors, remnants of old science experiments and a variety of small particles.

Three categories of space debris, depending on their size:

Category I (<1cm)
make significant damage to vulnerable parts of a satellite, shielding

Category II (1-10 cm)
seriously damage or destroy a satellite in a collision, no effective shielding

Category III (>10cm)
destroy a satellite in a collision, can be tracked(in GEO >1m), evasive maneuvers

INTRODUCTION TO SPACE DEBRIS

Space Surveillance Network (SSN)

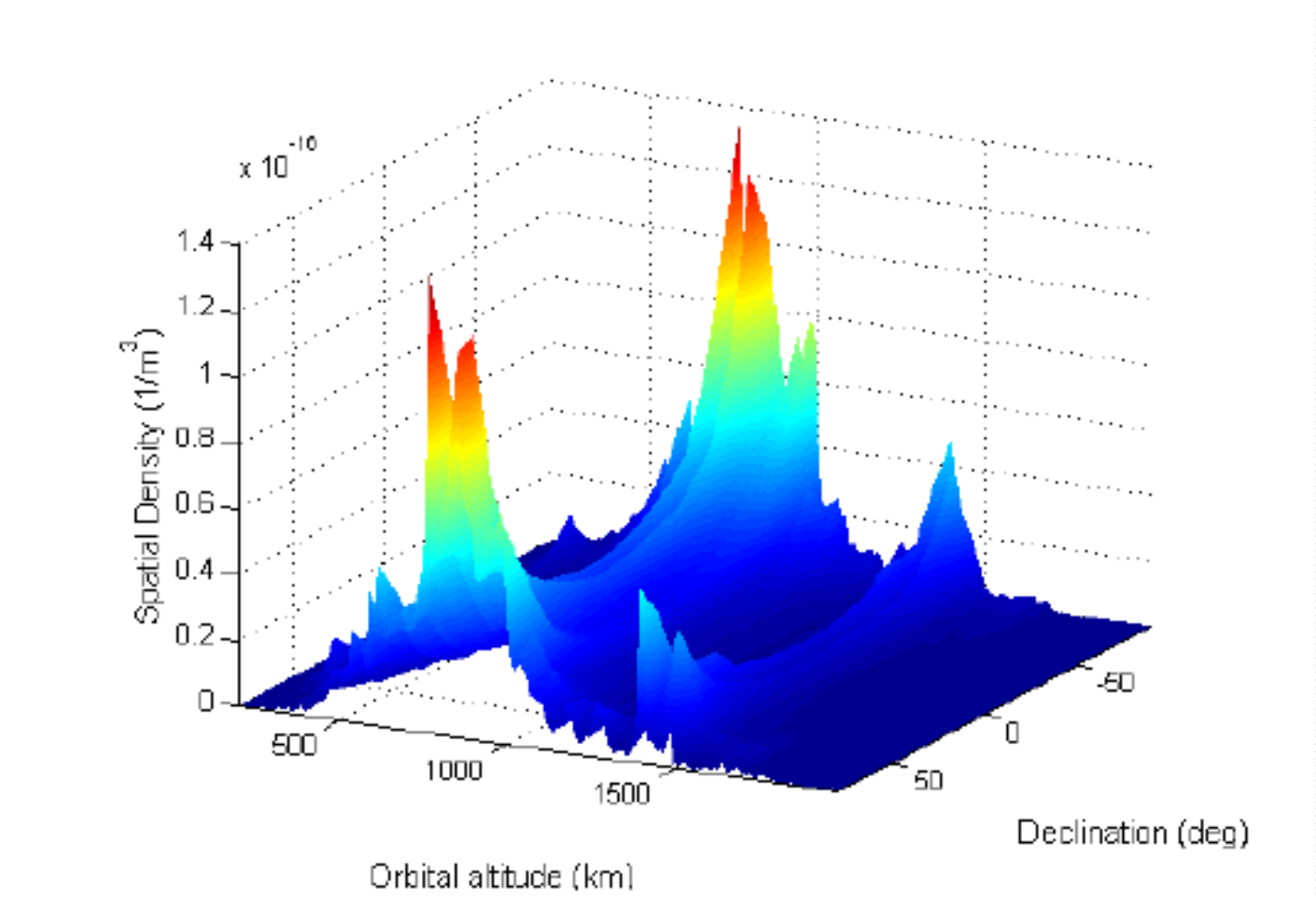
- currently more than 15,000 objects are tracked and kept in a catalog by SSN
- space debris number is much more than catalog

Debris Size	*0.1-1cm*	*1-10cm*	*>10cm*
Total Number at all altitudes	150 million	780,000	23,000
Debris in Low-Earth Orbit	20 million	400,000	15,000

Estimated amount of orbital debris, by size

The table isbased on data from European Space Agency MASTER 2005 debris environment, plus estimation of debris from the breakup events from 2006 to 2008.

INTRODUCTION TO SPACE DEBRIS

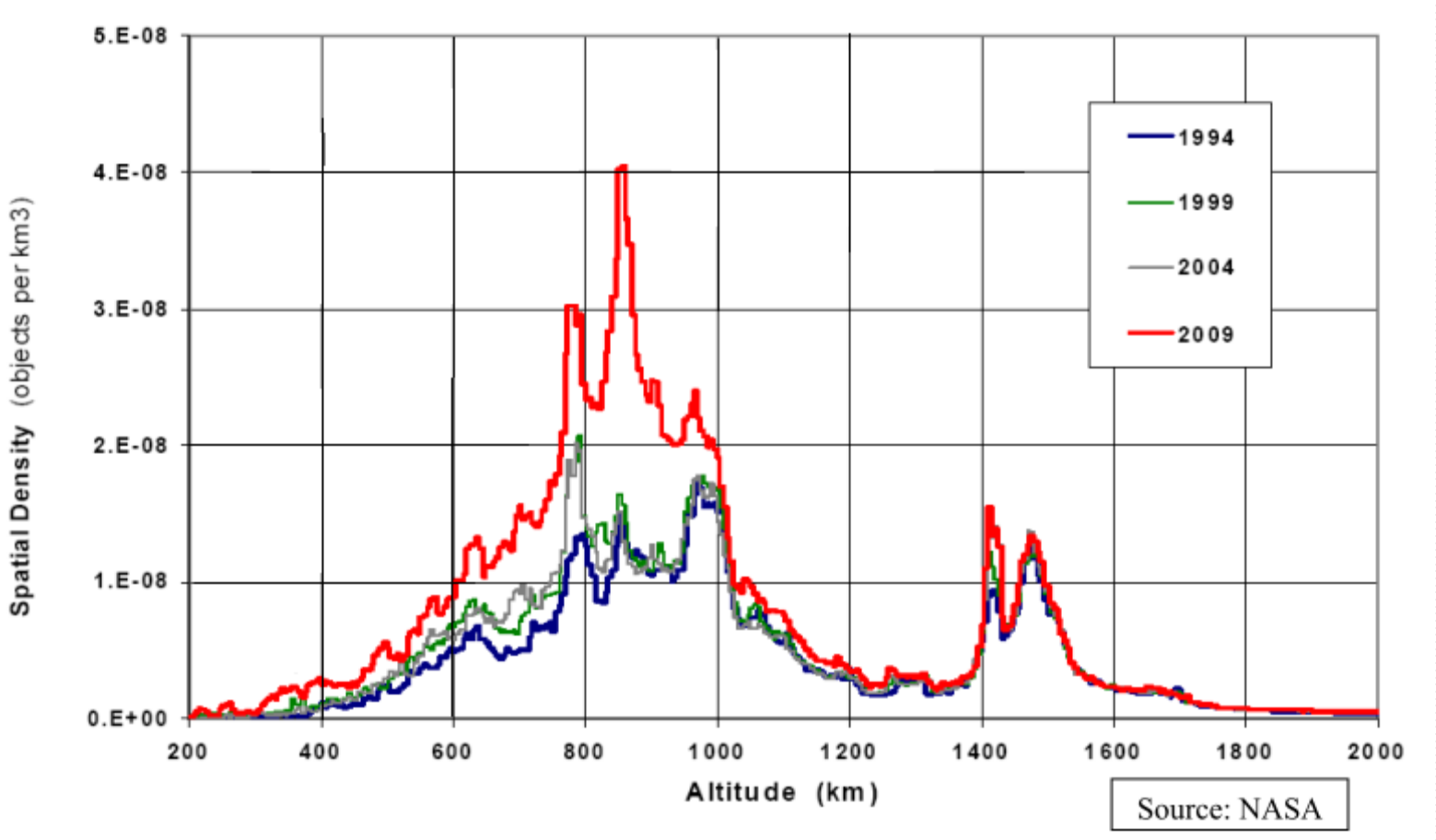


The distribution of low earth orbit (LEO) debris as a function of altitude and declination

(Data from Space Situation Report of August 25th 2008)

INTRODUCTION TO SPACE DEBRIS

The number of space debris increases very quickly



Graphic evolution of total trackable Low-Earth Obit (LEO) object population since 1994

Source: Marshall H. Kaplan, Survey of Space Debris Reduction Methods, AIAA SPACE 2009 Conference & Exposition 14 - 17 September 2009, Pasadena, California,AIAA 2009-6619

INTRODUCTION TO SPACE DEBRIS

Collision of Iridium33 & Cosmos2251

In an unprecedented space collision, 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.

Till now, over 1719 large fragments have been observed.

ACTIVE DEBRIS REMOVAL CONCEPT

ADR would be an effective way of stabilizing the space environment

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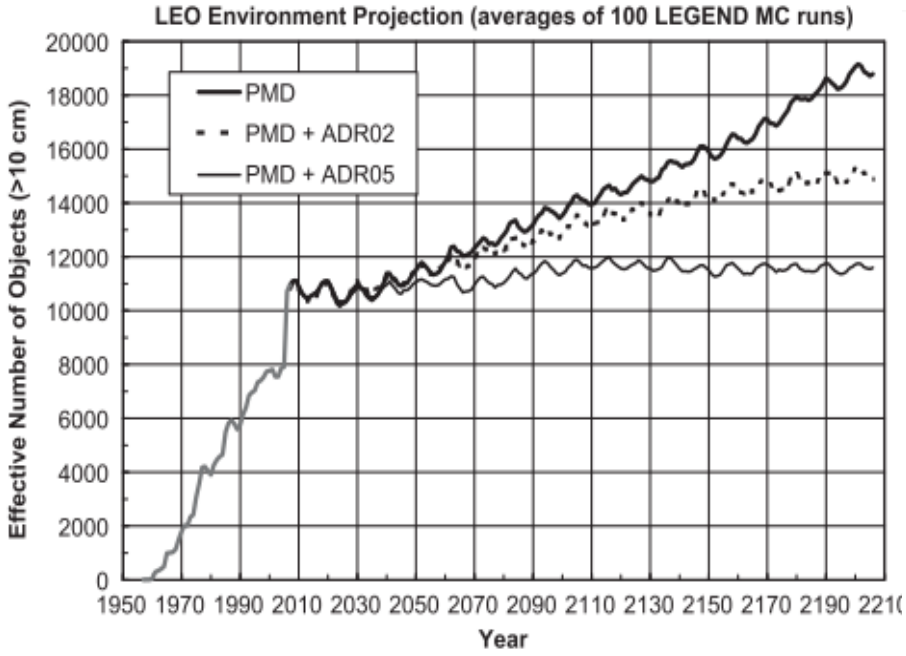

Comparison of three different scenarios
From top to bottom: postmission disposal (PMD) only, PMD and ADR of two objects per year, and PMD and ADR of five objects per year, respectively

Source: J.-C.Liou,N.L.Johnson,N.M.Hill, Controlling the growth of future LEO debris populations with active debris removal,Acta Astronautica 66 (2010) 648-653

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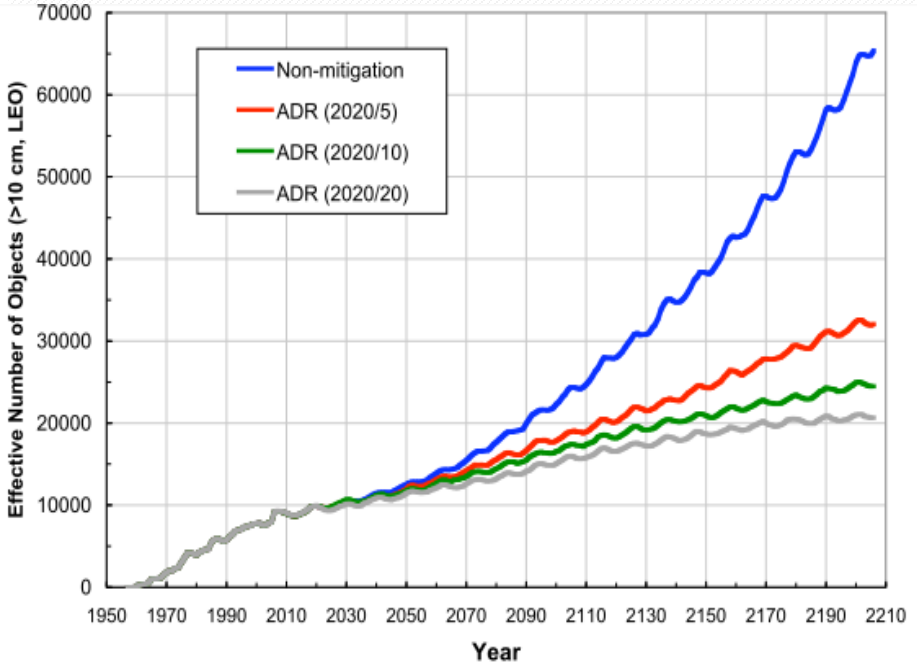


The debris population, non-mitigation and ADR with no PMD
2020/5: Five objects removed annually beginning in 2020
2020/10: Ten objects removed annually beginning in 2020
2020/20: Twenty objects removed annually beginning in 2020

Source: J.-C.Liou, Debris Removal: An Opportunity for Cooperative Research? , 25-26 October 2007,INMARSAT Headquarters, London

ACTIVE DEBRIS REMOVAL TECHNIQUES

Removing debris from LEO can make the LEO environment safe for the future space activities. And clearing GEO will keep the GEO orbit resources available.

	Catalog I (Size < 1cm)	*Catalog II (Size 1cm~10cm)*	*Catalog III (Size >10cm)*
LEO orbit 160km-2,000km	Space-based Magnetic Field Generator Sweeping/Retarding Surface Space-based Laser	Ground-/Air-/Space-based Laser	Drag Augmentation Device Magnetic Sail Momentum Tethers Electrodynamic Tethers Capture/Orbital Transfer Vehicle (Space Shutter)
GEO orbit About 35,000km			Solar Sail Momentum Tethers Capture/Orbital Transfer Vehicle (Using Net or Tentacles)

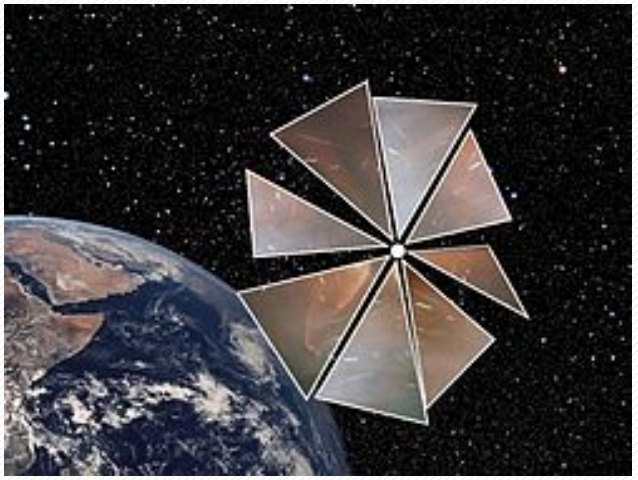
The active debris removal methods

ACTIVE DEBRIS REMOVAL TECHNIQUES

Briefly discuss

Solar sail

- an option for disposal of objects in very high orbits
- require no propellant storage or engines
- hard to deployment and control

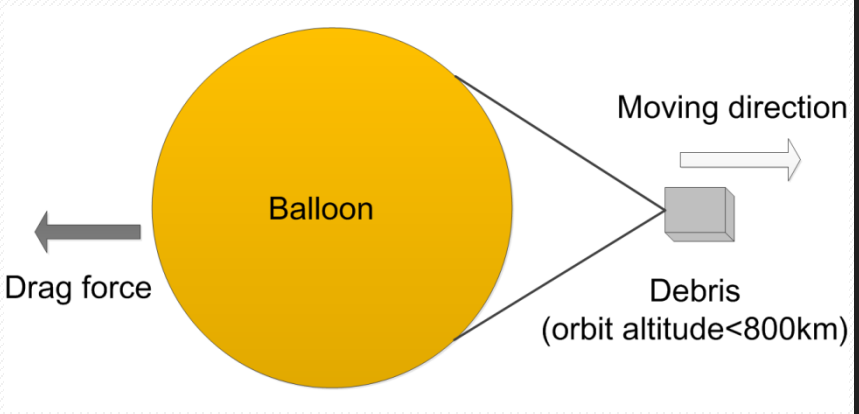


Solar sail

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

Drag augmentation device

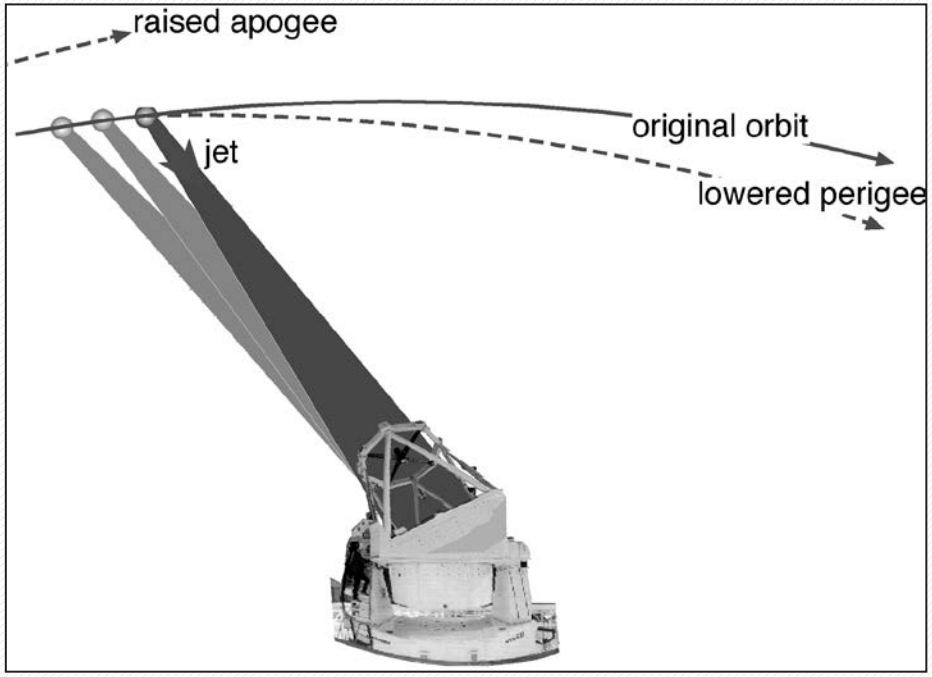
- could be a balloon deploy on space debris such as useless satellites
- not need to maintain any specific orientation
- no attitude control system is needed



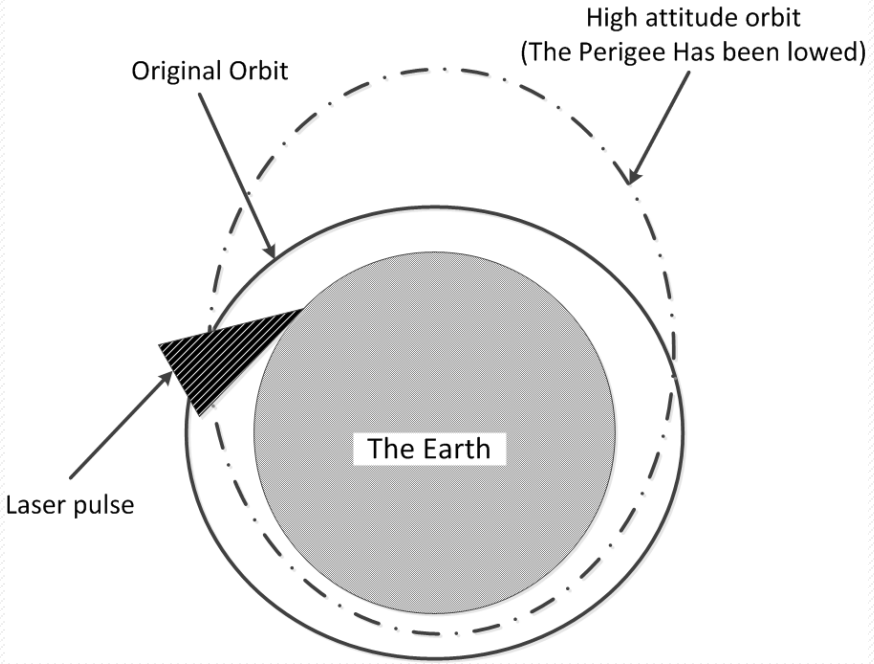
ACTIVE DEBRIS REMOVAL TECHNIQUES

Laser

- A feasible way to removal 1~10cm debris from LEO
- Burning or promoting



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



Use Laser to de-orbit debris

ACTIVE DEBRIS REMOVAL TECHNIQUES

Laser

Ground- and air-based laser

- ◆ provide a very high power
- ◆ technology is mature
- ■ energy lose significantly by the atmospheric absorption
- ■ could not be move freely in a huge range

Space-based laser

- ◆ no negative atmospheric effects
- ◆ be able to track and target debris with a much larger field of view
- ◆ focus on targets for longer periods of time
- ■ the cost is much larger to build, lunch and operate
- ■ can be a space-based weapon system

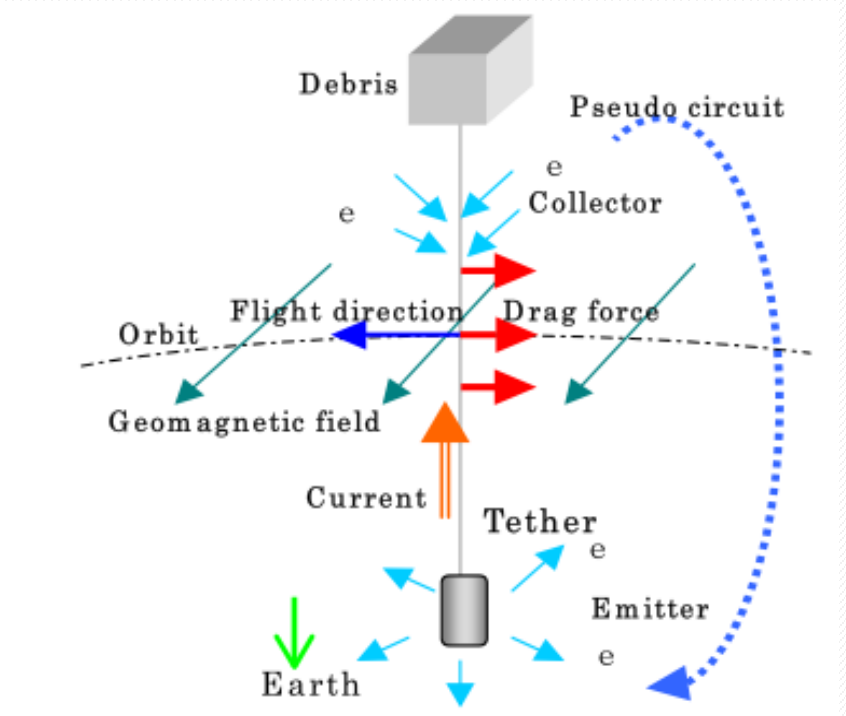
- A US project named ORION is aimed on the effectiveness of using ground-based laser to clear up the space debris in LEO. For most LEO debris, the change of its velocity can be completed in a single transit of the debris.
- In 2000 the US invested $ 200 million to research the ground-based laser experiment to clean up debris, and intended to have the experiment in 2003.

ACTIVE DEBRIS REMOVAL TECHNIQUES

Electrodynamic tethers and SDMR project

The Institute of Aerospace Technology, Japan Aerospace Exploration Agency (JAXA), is studying a micro-satellite system for active space debris removal in LEO. They named it Space Debris Micro Remover (SDMR).

SDMR use a small satellite to capture a space object and de-orbit the object by the electro-dynamic tether (EDT) technology.



Principle of electro-dynamic tether

Source: Shin-ichiro, et.al., Space Debris Removal System using a Small Satellite, 57th International Astronautical Congress, Valencia, Spain, Oct. 2-6, 2006

ACTIVE DEBRIS REMOVAL TECHNIQUES

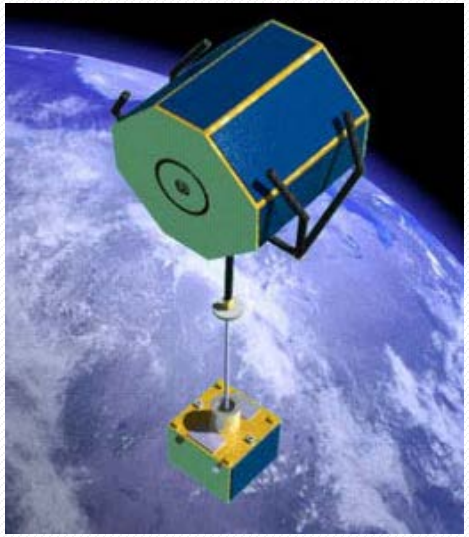
Electrodynamic tethers and SDMR project

The mission profile

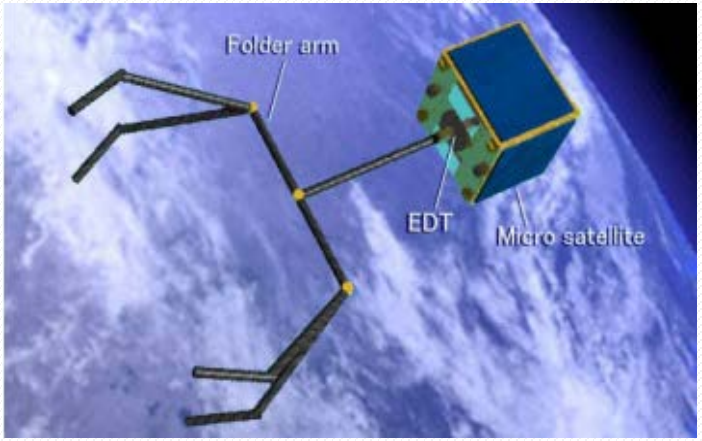
1. Rendezvous with the debris object (target) and measure its motion.
2. Fly around the target, and make a final approach to capture it.
3. Capture the target using an extensible folder arm.
4. Extend an electro-dynamic tether fixed at the root of the folder arm.
5. Autonomous control of tether inclination.

Key technologies

1. An efficient orbital transfer technology: Electro-dynamic Tether
2. Navigation to and around the debris object: Machine vision/image processing
3. Robotic capture: Extensible light arm to capture the debris object.



Concept of debris removal



Space debris micro remover satellite

Sorce: Shin-ichiro, et.al., Space Debris Removal System using a Small Satellite, 57th International Astronautical Congress, Valencia, Spain, Oct. 2-6, 2006

ACTIVE DEBRIS REMOVAL TECHNIQUES

Capture vehicle and ROGER project

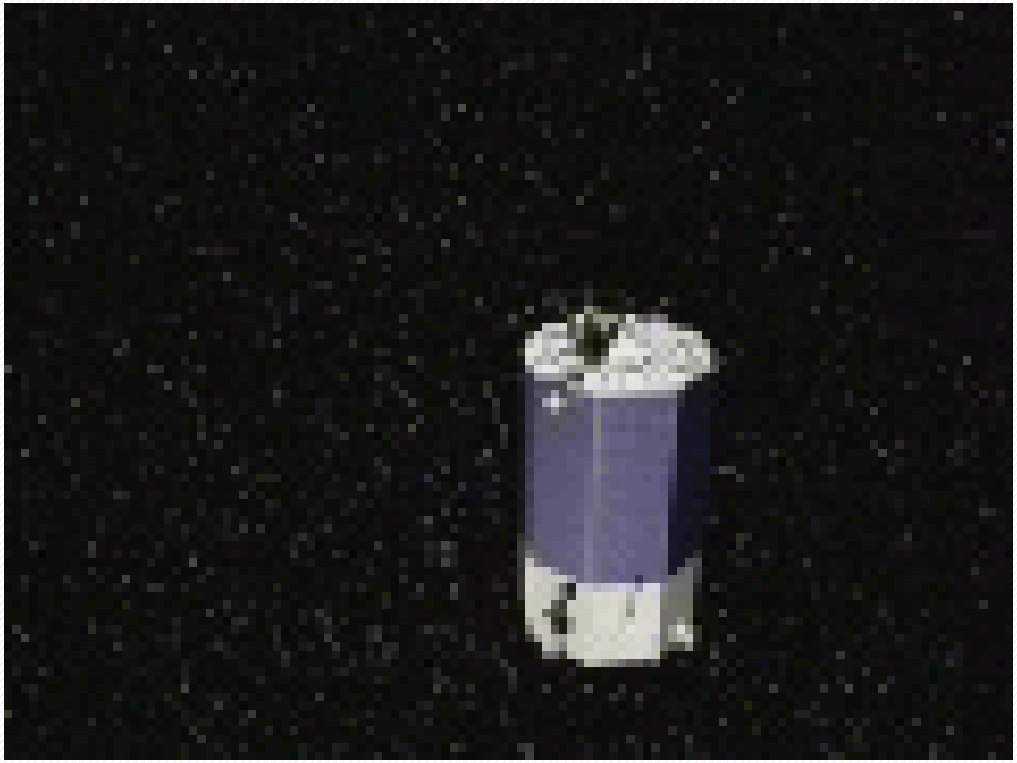
The Robotic Geostationary Orbit Restorer, ROGER project which started in 2002 by European Space Agency (ESA), is a new concept for an in-orbit roving debris removal system.

ROGER can be tasked to approach and capture a redundant or non-operational satellite in the Geostationary (GEO) orbit and tow it into a parking or graveyard orbit(GYO).

Different configurations of the ROGER spacecraft have been identified. These differ not only in the basic satellite bus but mainly in the means used to "capture" a target satellite.

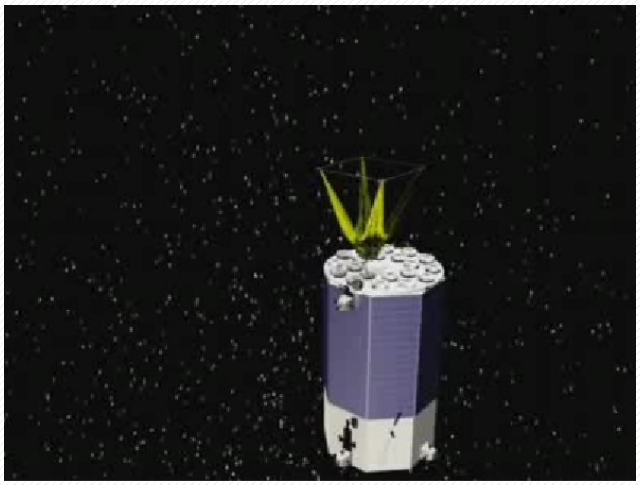
ACTIVE DEBRIS REMOVAL TECHNIQUES

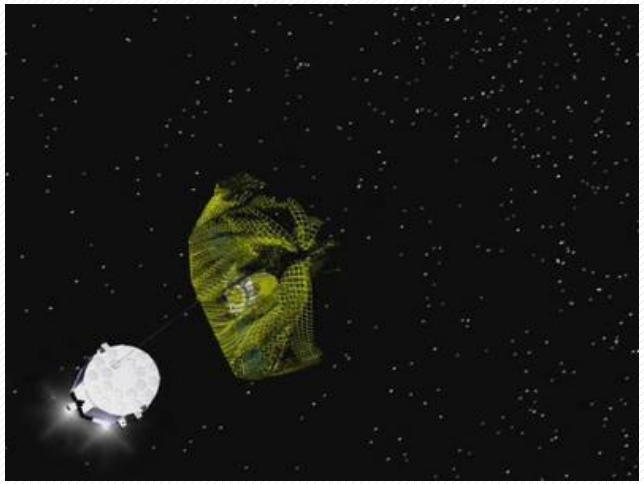
ROGER Spacecraft by the ASRIUM team



Source:http://www.esa.int/TEC/Robotics/SEMTWLKKKSE_0.html

This kind of Roger use throw-nets to capture its target, and it has 20 nets.





ROGER Spacecraft(ASRIUM team)

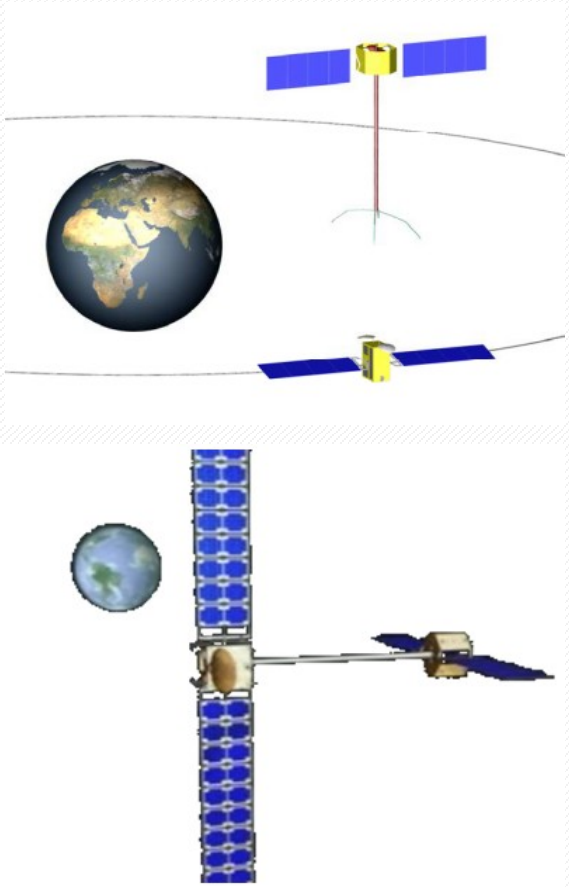
Source:
http://www.esa.int/TEC/Robotics/SEMTWLKKKSE_0.html

ACTIVE DEBRIS REMOVAL TECHNIQUES

ROGER Spacecraft by the QinetiQ team

Source:http://www.esa.int/TEC/Robotics/SEMTWLKKKSE_0.html

It uses tentacles to capture targets
If there is an incapacitated GEO satellite in the orbit as a target, the ROGER spacecraft will approach the malfunctioning satellite with its boom and deploy octopus grasping system. The satellite will be captured by the fingers and then towed away into the GYO.



ROGER Spacecraft(QinetiQ team)

Source:
http://www.esa.int/TEC/Robotics/SEMTWLKKKSE_0.html

ACTIVE DEBRIS REMOVAL TECHNIQUES

Capture vehicle and ROGER project

The technical challenges

1. the ability to safely capture a target
2. the number of target satellites within a multiple target mission is limited
3. control both the ROGER satellite and the tandem "ROGER plus target satellite"
4. capability of dextrous robotics
5. the supervision, control and eventually tele-manipulation of ROGER from ground

CHALLENGES IN INSTITUTING EFFECTIVE SPACE DEBRIS REMOVAL

- ADR technology require substantial time and money to develop and deploy (It costs around $10,000 per kilogram to lunch anything into orbit)
- a lack of clear policy on international level
- the similarities between space debris removal systems and space weapons
- starting the process of active debris removal

THANKS

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LEO Low Earth Orbit 160km - 2,000km from the ground

GEO Geostationary Earth Orbit about 35,000km from the ground

PMD Post mission disposal, a mitigation measures such as let a rocket upper stage reenter the earth itself after the mission

ADR Active Debris Removal

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