Best Mitigation Paths To Effectively Reduce Earth's Orbital Debris

NASA-Marshall Space Flight Center's Advanced Concepts Office (MSFC-ED04)

Bruce M. Wiegmann

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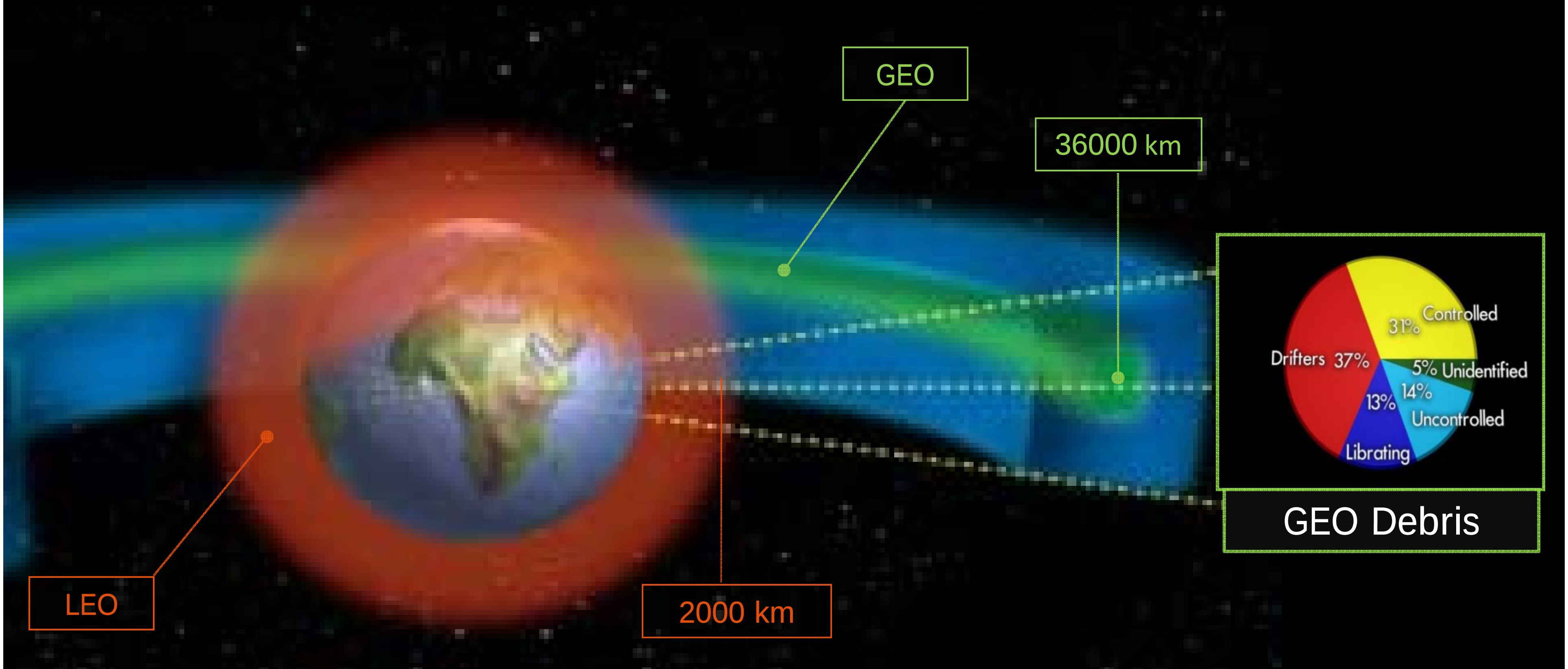
Outline

- The Orbital Debris Environment
- Near-term Needs to Minimize Kessler Syndrome
- Survey of Active Orbital Debris Mitigation Strategies
- Best Paths to Actively Remove Orbital Debris
- Technologies Required for Active Debris Mitigation
- Conclusions

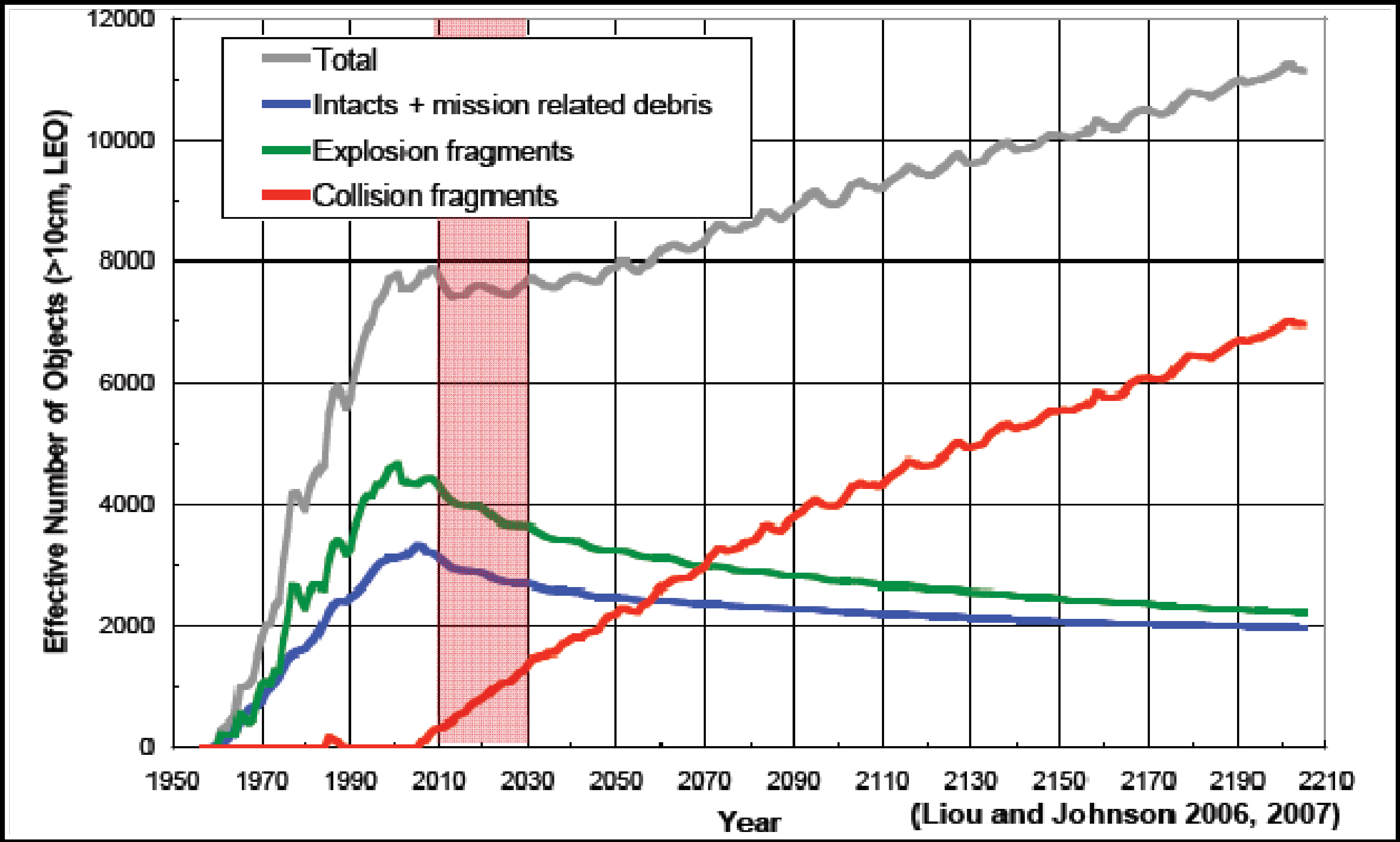
Orbital Debris Environment (June 2008)



- 19,000 objects tracked by the US Space Surveillance Network**
- There are approximately 900 operational spacecraft currently in orbit. Of those, approximately 800 are maneuverable. *
- 12,000 objects > 10 cm in diameter***
- 18,000 objects > 5 cm or greater in size.*
- 300,000 objects > 1 cm in size or greater. *

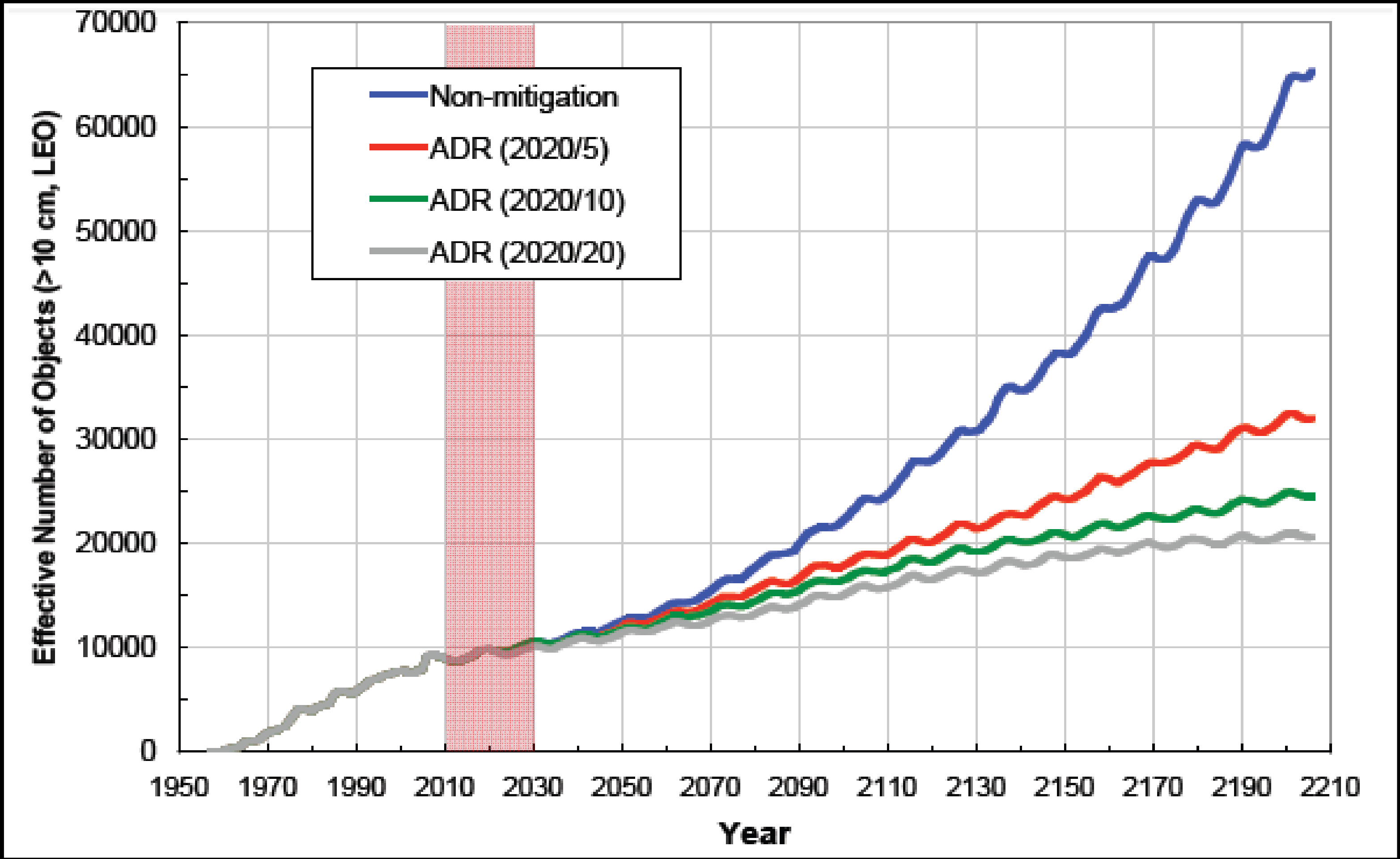
* From US Congressional Hearing Charter April 28, 2009
**From prepared testimony of NASA's N.L. Johnson at April 28, 2009 Congressional Hearing
*** from ESA Space Debris web site

Projected Growth of LEO Populations
(no new launches beyond 1/1/2006)



Active debris removal needs to be fielded within the next 20 years to minimize Kessler Syndrome effects

Active Removal of LEO Debris Minimizes the Kessler Syndrome



Analysis shows that the Kessler Syndrome can be minimized by removing from 5 to 20 LEO objects per year

* Chart from N. Johnson's "**Debris Removal: An Opportunity for Cooperative Research?**" presentation at INMARSAT Headquarters, London (25-26 October 2007) "

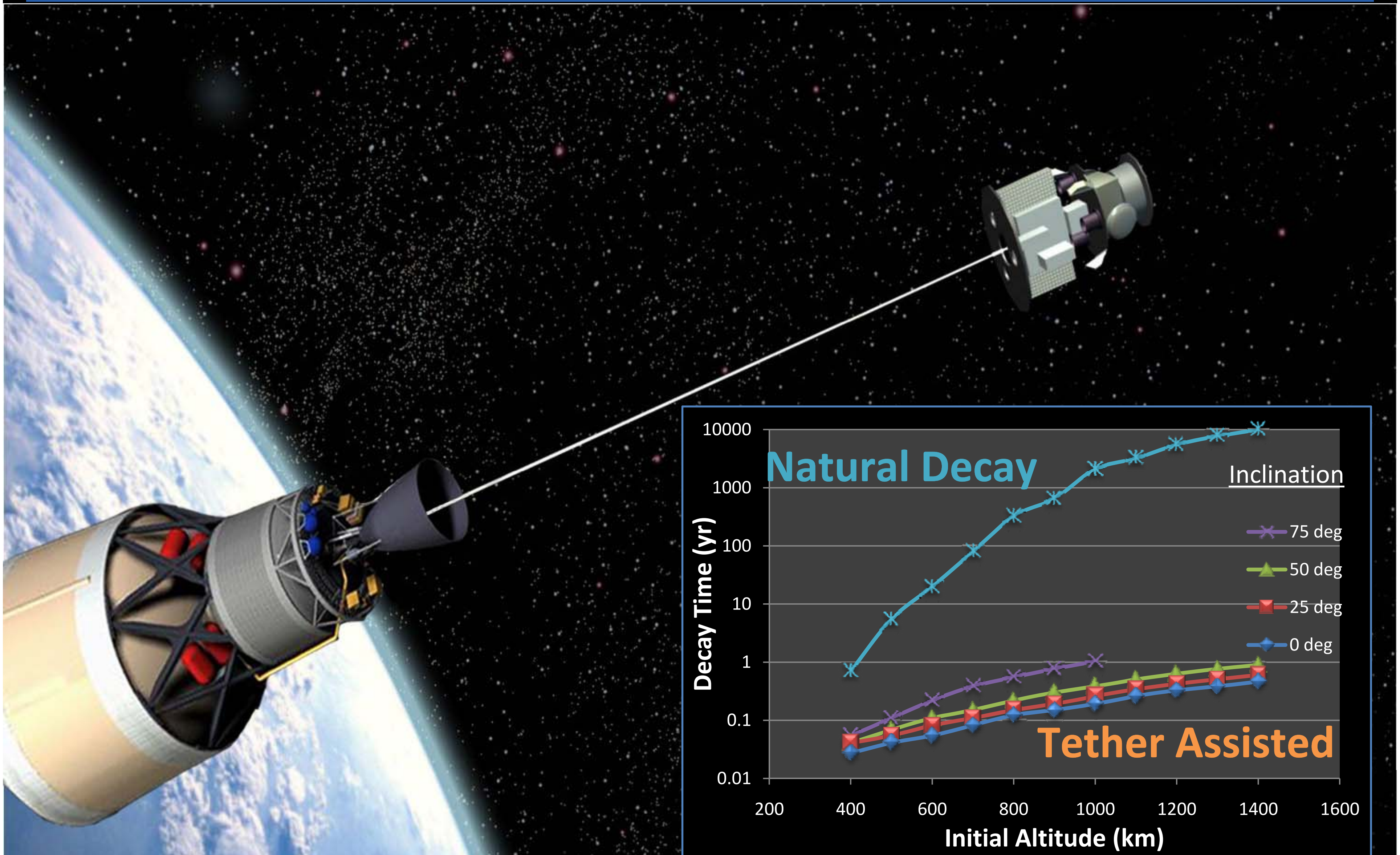
Survey of Solutions for Active Orbital Debris Removal

	LEO			GEO
Debris Size	< 1 cm	1 to 10 cm	Large (derelict spacecraft or expended rocket bodies)	Large (derelict spacecraft or expended rocket bodies)
Number of Objects	Millions	~ 150,000 objects in LEO	approximately 20,000 (>10 cm)	Hundreds
Potential Options	Space-based Magnetic Field Generator	Space Based Laser	Magnetic Sail	Solar Sail
	Sweeping/Retarding Surface (balloon, film, foam ball, etc.)	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 as studied by MSFC in the 1990s show promise. Advances in pico pulsed lasers may bring desirable effects. All 1-10 cm debris (>150,000 objects) 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 drag device must be attached to the large spacecraft via AR&D or other methods. The drawback to tethers is the re-entry point is not controllable whereas a propulsive de-orbit 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 needed. Propulsion options between storable or ion systems do not seem to be the system driving design factor.

1) Alexander Karl, "Active Removal of Space Debris – Discussing Technical & Economical Issues", IAC-06-B6.4.04
2) USSTRATCOM Global Innovation and Strategy Center, "Eliminating Space Debris: Applied Technology and Policy Prescriptions", Jan 2008

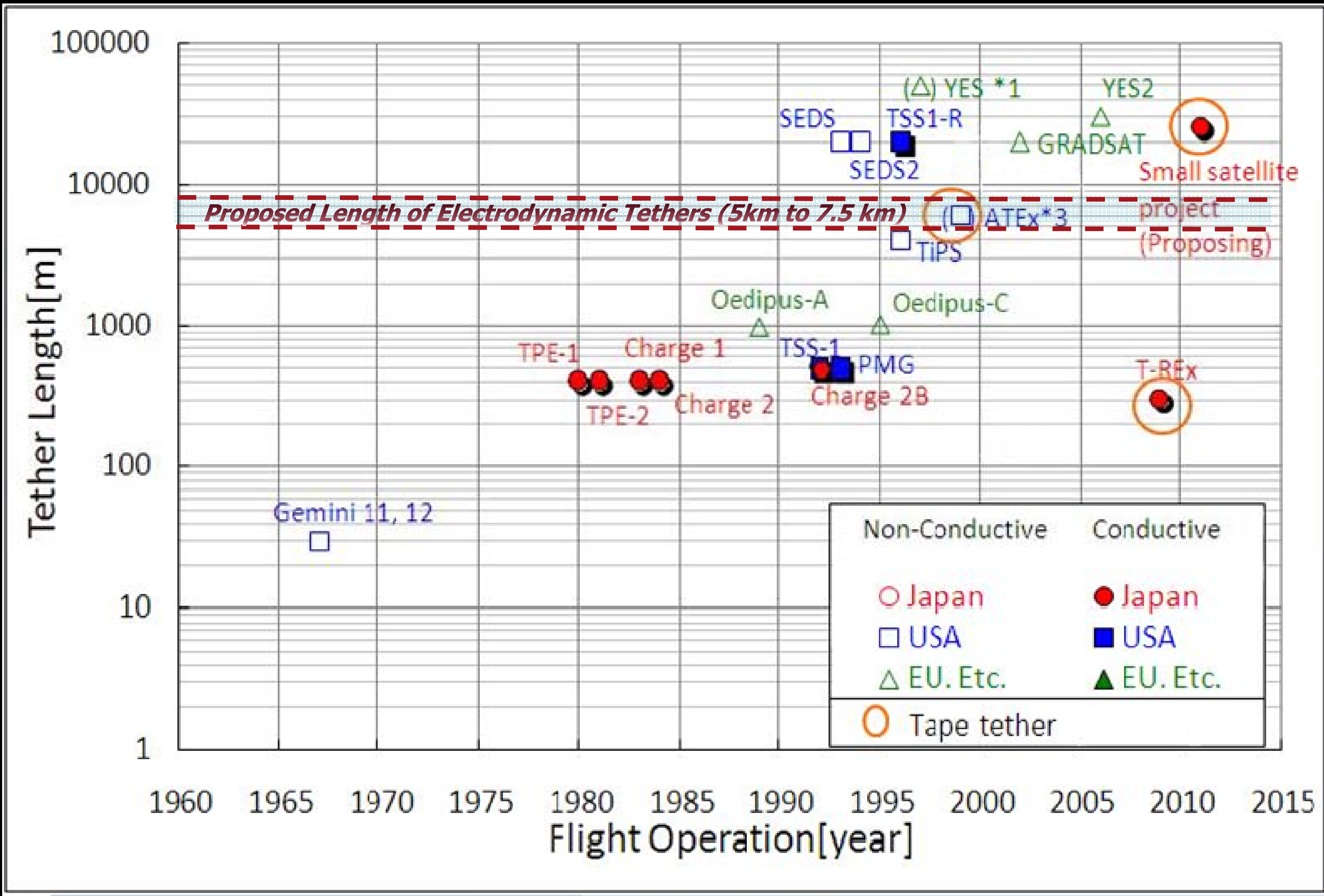
There is no immediately available, single optimum technical solution for all aspects of orbital debris removal

Satellite Decay Times with an EDT versus Natural Decay Time



Time to de-orbit a 1500 kg spacecraft to 250 km with a 7.5 km Terminator Tether ™ with a mass of 1% of the spacecraft (1)

Chronology of Tethers in Space



Tether Technology has matured and is ideally suited for Active Debris Removal

Active Orbital Debris Removal Methods for GEO Debris

- **Non-operating satellites or operational satellites in GEO must be moved to disposal or graveyard orbits which are 300 km above GEO.**
  - Less energy required to place dead satellite in disposal orbit versus energy required to de-orbit satellite.
  - Active spacecraft designed to accomplish GEO disposal missions could be designed for numerous disposal missions as the mass impacts for the total delta V necessary are minimal when compared to overall system mass.
  - Spacecraft design trades would look at differences in propulsion techniques:
    - Storable propellants
    - Ion propulsion

A GEO based space tug with Autonomous Rendezvous & Docking or grappling capability may be the best solution for this problem

Technologies Required for Active Debris Removal

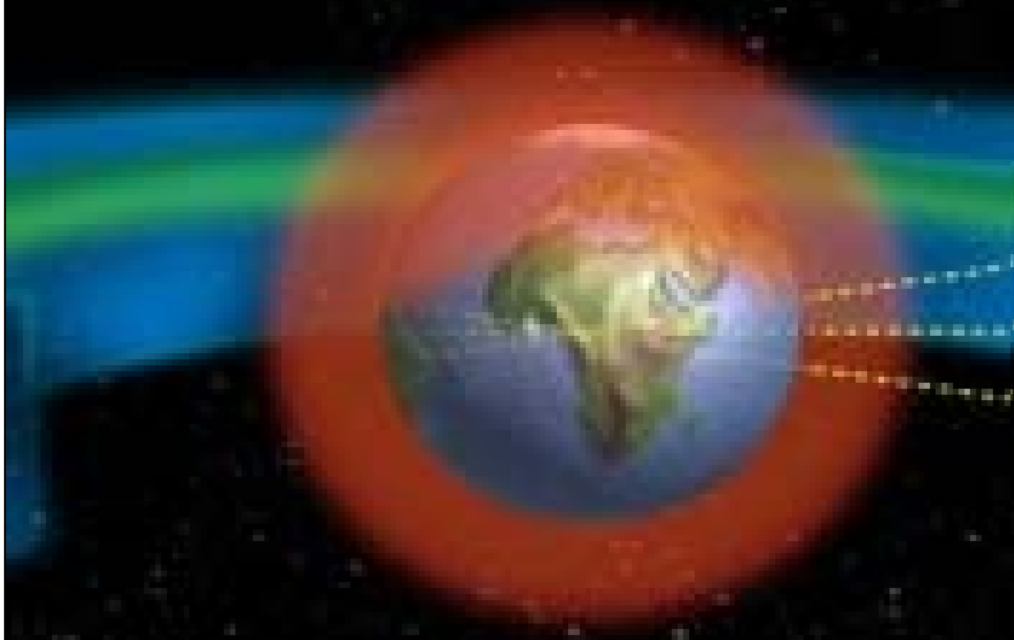
Technologies required to develop and demonstrate Active Orbital Debris Removal exist and are at mature TRLs now

SYSTEMS OF AEROSPACE DESIGN

- **Autonomous Rendezvous & Docking –DOD & NASA**
  - The DARPA Front End Robotic Enabling Near-Term Demonstrations (FREND) project will help improve the robotic arms necessary to remove large objects
  - Autonomous Space transfer and Robotic Orbiter (ASTRO)
  - Demonstration of Autonomous Rendezvous Technology (DART),
- **Airborne or Ground Based Lasers – DOD**
- **Tethers - USA (NASA & DOD), ESA & JAXA**
- **Ion Propulsion - NASA**

A system of systems could be fielded within a few years given appropriate levels of funding

Conclusions



Technology System Demonstrators need to be funded soon.

Active Orbital Debris removal system demonstrators can integrate the technologies available today and be assessed for overall effectiveness.

References

- Slide 4 - Projected Growth of LEO Populations
- Slide 5 - Active Removal of LEO Debris Minimizes the Kessler Syndrome

Johnson, N., "Debris Removal: An Opportunity for Cooperative Research?", Improving our Vision II: Building Transparency and Cooperation, INMARSAT Headquarters, London, UK, 25-26 October 2007

- Slide 6 - Survey of Solutions for Active Orbital Debris Removal

1) Alexander Karl, "Active Removal of Space Debris – Discussing Technical & Economical Issues", IAC-06-B6.4.04
2) USSTRATCOM Global Innovation and Strategy Center, "Eliminating Space Debris: Applied Technology and Policy Prescriptions", Jan 2008

- Slide 7 - Satellite Decay Times with an EDT versus Natural Decay Time

•(1) Pardini, C., T. Hanada and P.H. Krisko, Benefits and Risks of Using Electrodynamic Tethers to De-Orbit Spacecraft; Document No IAC-06-B6.2.10

- Slide 8 - Chronology of Tethers in Space

Watanabe, T., Fujii, H., Mazawa, T., Sukekawa, M., Kojima, H., Sahara, H., "Experiments of Electro Dynamic Tether System Using Bare Tape Tether and Development of the Tape Tether Deplorer", 2009-c-31

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BACKUP

Recent Conclusions from NASA & ESA Experts Regarding Need for Active Debris Removal

- **The 5th European Conference on Space Debris (April 2009)**

Main Conference Finding:
However, it is common understanding that mitigation alone cannot maintain a safe and stable debris environment in the long-term future. ***Active space debris remediation measures will need to be devised and implemented.***

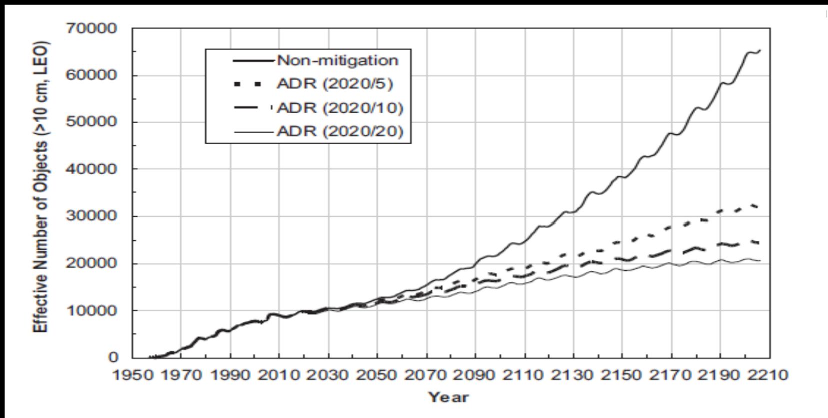
- **Recent Congressional Testimony Concerning Orbital Debris (April 28, 2009)**

Written testimony of Mr. N. Johnson, Chief Scientist for Orbital Debris – NASA at "*Keeping the Space Environment Safe For Civil and Commercial Users*"

"The recent collision of two intact satellites underscores a NASA 1970s-era finding, …. *that the amount of debris already in Earth orbit is sufficient to lead to more accidental collisions, which in turn will lead to an unintended increase in space debris and increased risk to operational space systems.* **….** ***The most effective means of limiting satellite collisions is to remove non-functional spacecraft and launch vehicle orbital stages from orbit.*** *However, the remediation of the near-Earth space environment presents substantial technical and economic challenges."*

Benefits of Active Debris Removal

(Source: NASA/JSC/L.-C. Liou; N.L. Johnson , July 16, 2009)



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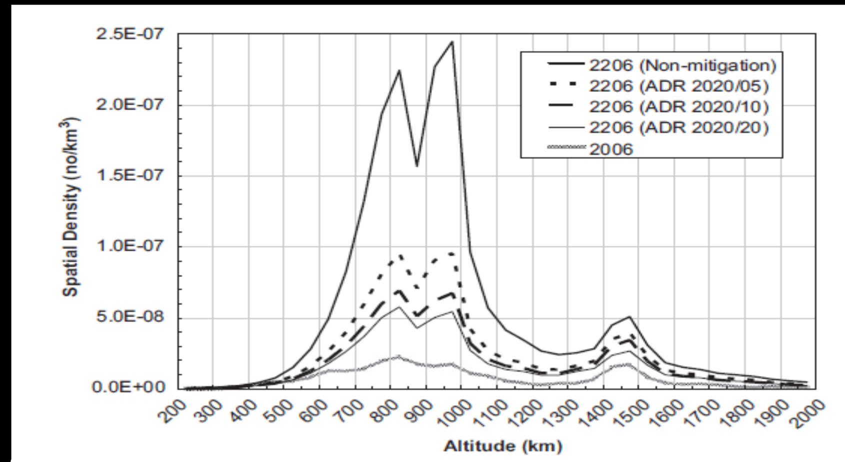

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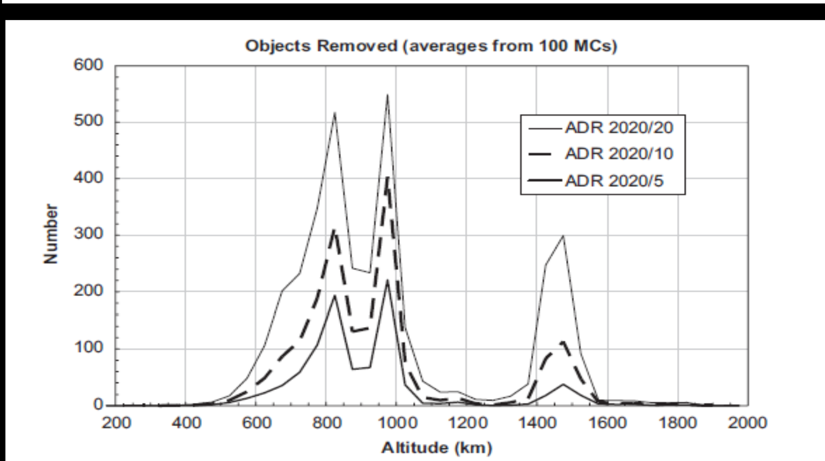

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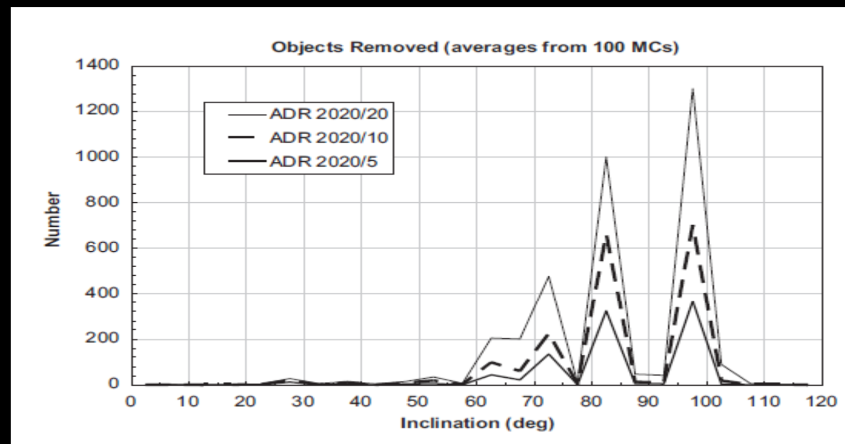

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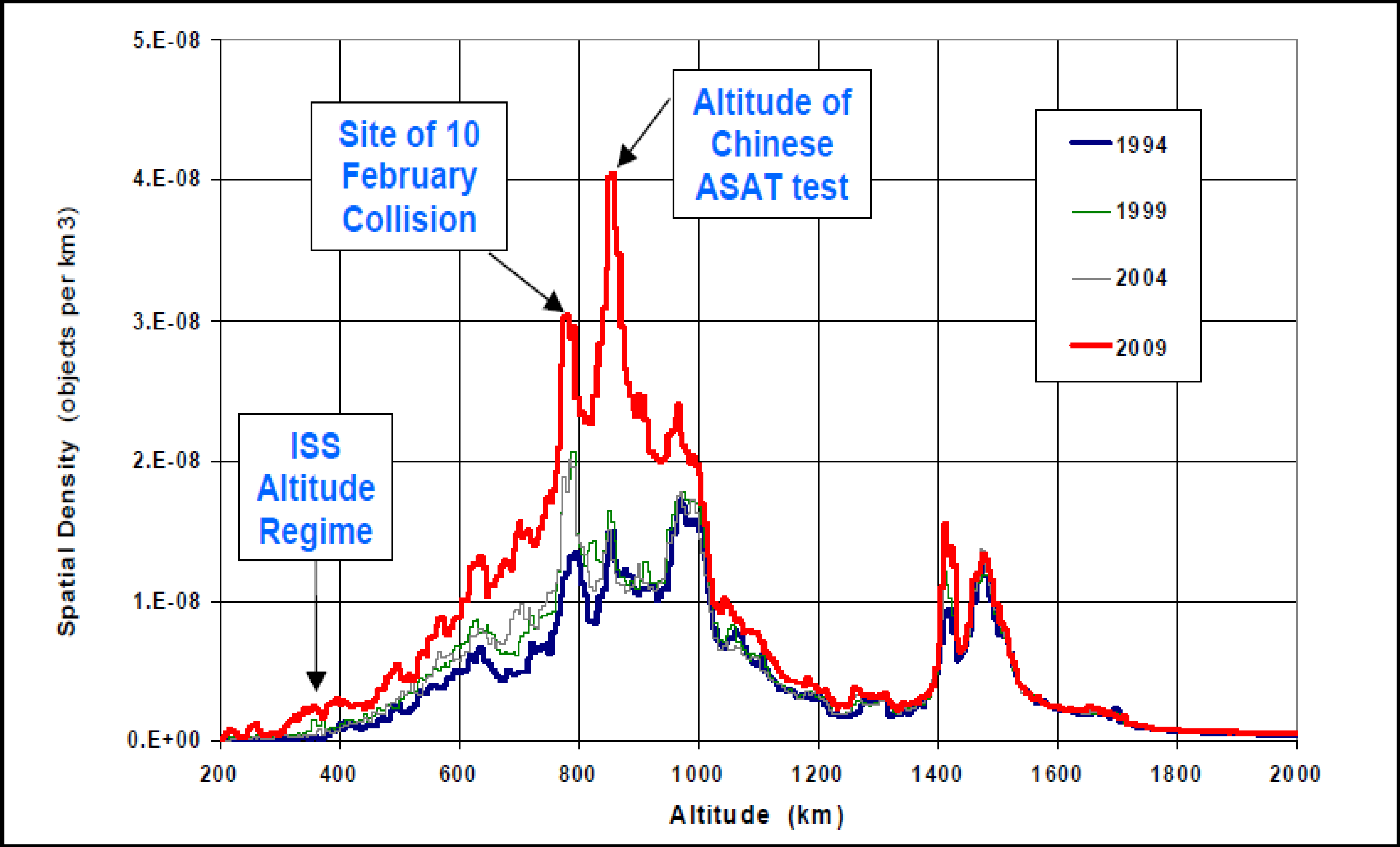
Positive results of Active Debris Removal by the removal of 5, 10, or 20 objects removed per year.

Impacts to LEO Debris Density from PRC ASAT Test and Iridium/Cosmos Collision



The growth of the cataloged satellite population during the past 15 years has been primarily influenced by China's ASAT test in January 2007.