Overview of Active Debris Removal

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Space sustainability

- Space provides many benefits to everyone on Earth
  - Socioeconomic
  - National security
  - International security and stability

- More and more countries are using space
  - Ten countries have the ability to launch satellites
  - Over 60 entities now own or operate satellites

- The long-term sustainability of Earth orbit is in jeopardy, in part due to the growth of space debris and the increase in use of space

What's in orbit now?

Active Satellites

Total number of operating satellites: 999			
LEO: 470	MEO: 69	Elliptical: 36	GEO: 424
United States: 442	Russia: 103	China: 86	

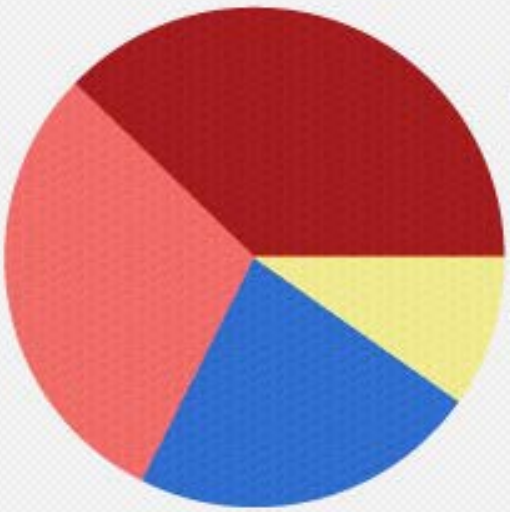
Space Debris

Larger than 10 cm	16,000	Sources of new debris
Between 1 and 10 cm	500,000	Can cause major damage
Smaller than 1 cm	Lots	Can cause minor damage

David Wright, Scientificamerican.com

Who's responsible?

An interesting way of looking at who owns objects in space is to consider the percentage of ownership by number of objects (left) and by mass of objects (right).

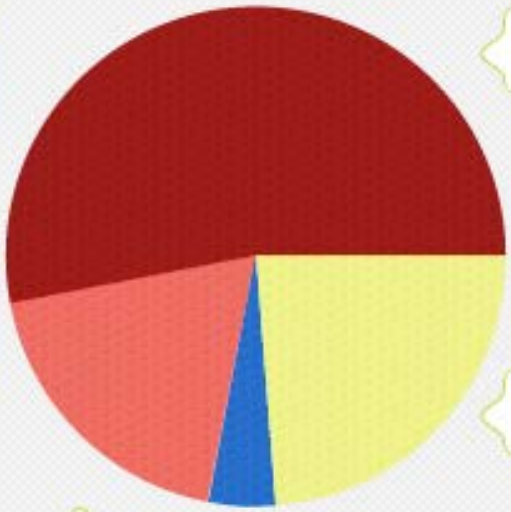


Russia*: 37.8%
Total Objects: 6,087

Others: 9.7%
Total Objects: 1,565

USA: 30.1%
Total Objects: 4,850

China: 22.4%
Total Objects: 3,615



Russia*: 53%

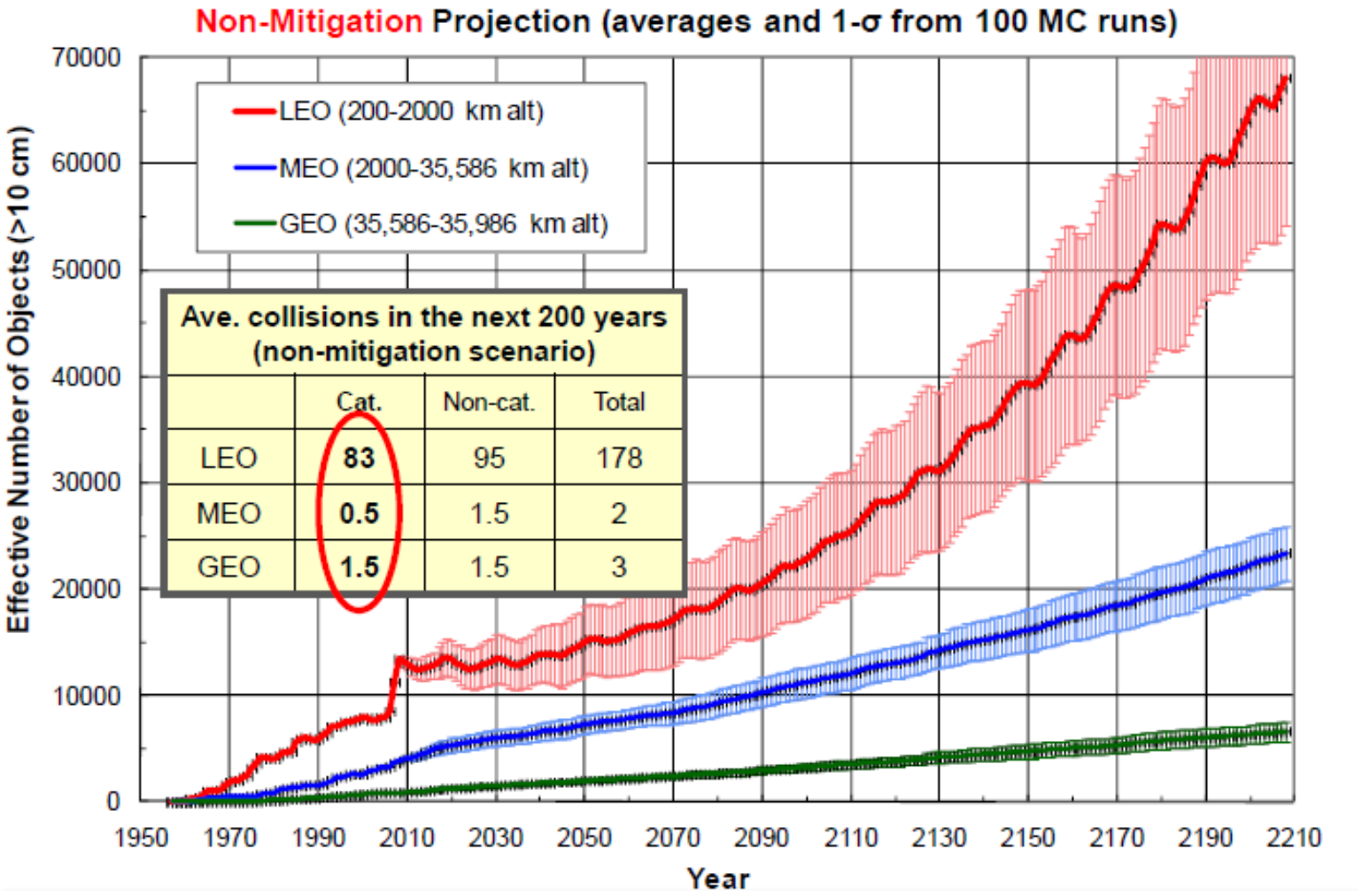
Others: 24%

USA: 19%

China: 4%

David Wright, Scientificamerican.com
As of January, 2012

The next 200 years, without any action

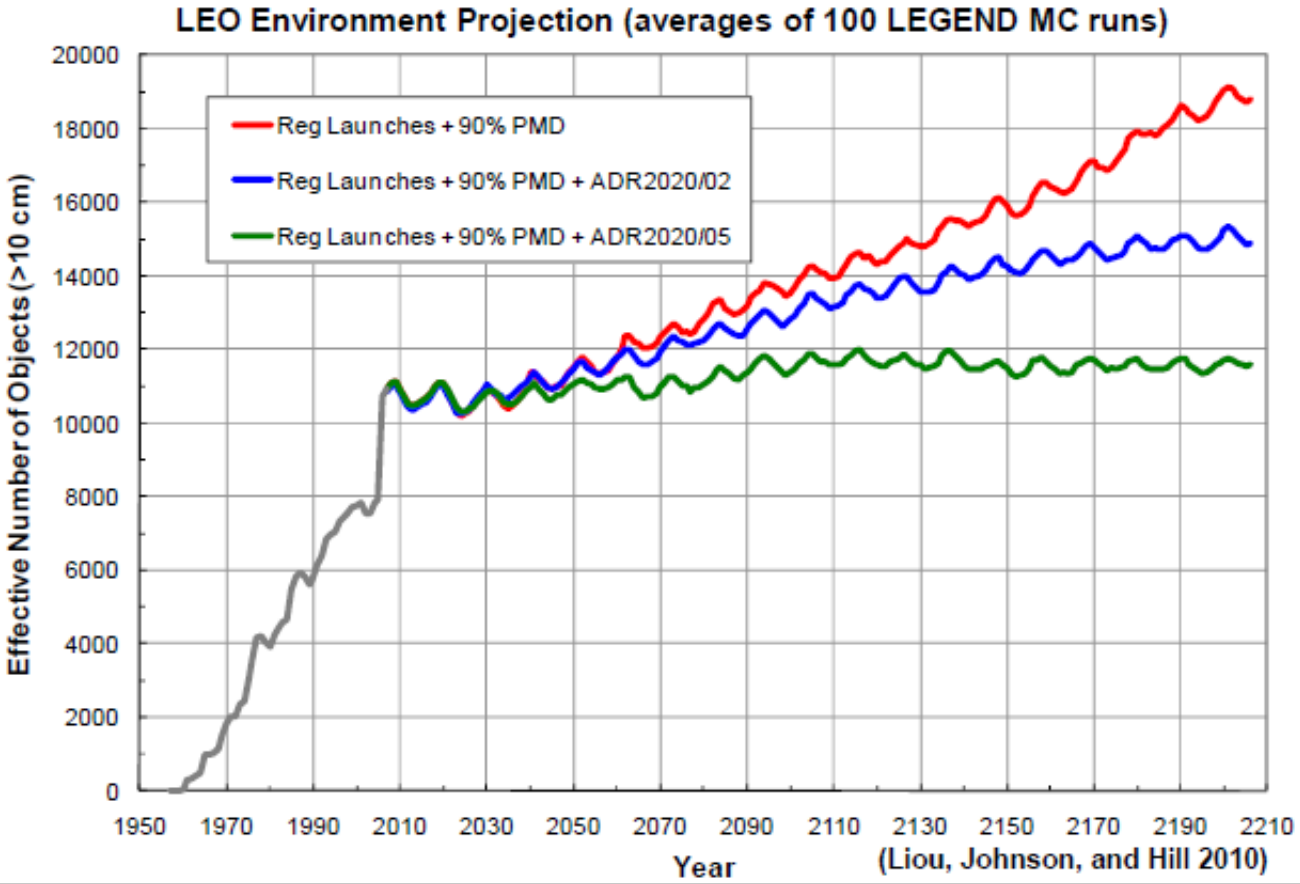


Ave. collisions in the next 200 years (non-mitigation scenario)

	Cat.	Non-cat.	Total
LEO	**83**	95	178
MEO	**0.5**	1.5	2
GEO	**1.5**	1.5	3

J-C Liou, NASA Orbital Debris Program Office

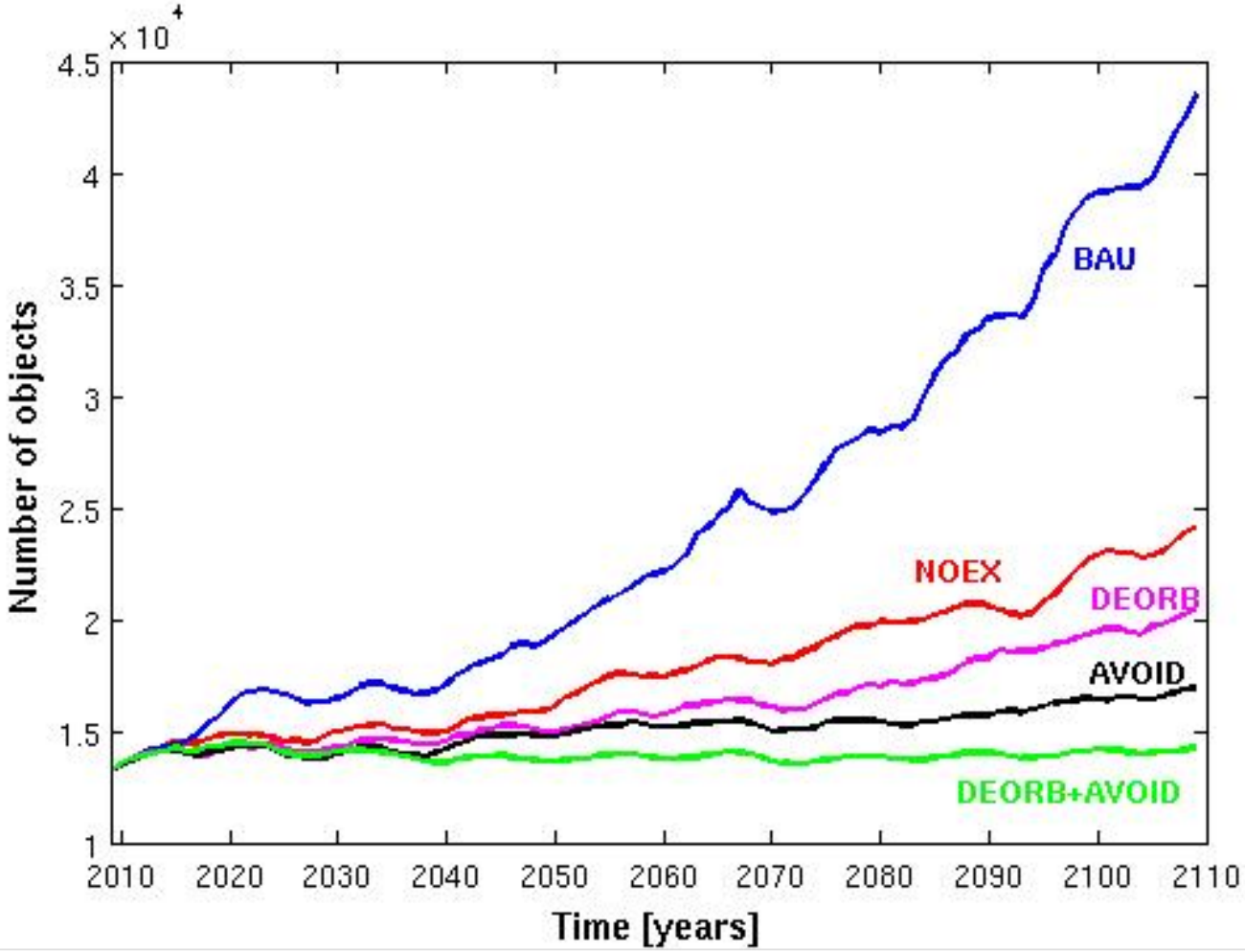
Long term need is for PMD + COLA + ADR



- PMD scenario predicts the LEO populations would increase by ~75% in 200 years
- LEO environment can be stabilized with PMD and a removal rate of 5 obj/year

J-C Liou, NASA Orbital Debris Program Office

ESA models show the same



- Business as Usual
- No Explosions
- Remove 5 large debris/year
- COLA for all active satellites

Rudi Jehn, ESA/ESOC, using SDM software

What is the objective of ADR?

- If the objective is to reduce the collision threat for active satellites in the short-term

  ➡ ADR goal and priority should be to remove the "bullets" (debris objects 1 to 10 cm in size with high Probability of Collision with large objects

- If the objective is to stabilize the long-term growth in the debris population

  ➡ ADR goal and priority should be to remove the "cars" (debris objects with the highest value of Mass x Probability of Collision)

Main points

- Without active debris removal, the LEO debris population will see a non-linear growth in the future, resulting in many more collisions
- ADR is not a high priority for MEO and GEO, ***if*** current debris mitigation and end-of-life disposal measures are implemented and followed
- Collision avoidance helps protect active spacecraft, but does not significantly reduce future growth in the debris population
- Removing large debris objects helps stabilize population growth over the long-term, but does not protect satellites in the short-term.

Summary of ADR techniques vs size

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

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

Some technical challenges

- Consensus on objective/priority for ADR (small or large objects) and a metric for determining which objects to go after
- Tumbling/spinning and fragile/unstable objects during capture, docking, and acceleration
- Controlling atmospheric re-entry of large objects to prevent potential damage to humans/property on Earth
- Screening laser firings into space to de-conflict with operational satellites

The stark reality of economics

- The odds of developing an economic incentive mechanism for removing space debris in LEO are ***extremely small*** because there's ***little direct economic value in LEO***
  - Nearly all the economic activity in space takes place in GEO
    - Total value of global space activities: $280 billion
    - Total private benefits from LEO: ~$3 billion
  - Almost all users of LEO are public entities deriving social benefits

- The ***debris problem was largely created by governments*** using public money (legacy debt that needs to be dealt with)

- Any ***funding of ADR activities is likely to come from public money*** and either be governments conducting missions themselves or purchasing services from private sector

Conclusions

- All models currently indicate that ADR is a necessary part of managing debris, protecting satellites, and ensuring the long-term sustainability of Earth orbit
- Technical community needs to do more research on feasible ADR techniques, and metrics for determining objectives and priorities
- Non-technical community needs to work with the technical community on the legal and policy issues
- An international, cooperative technology demonstration mission could promote progress on both the technical and non-technical fronts

Questions?

Thank you

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