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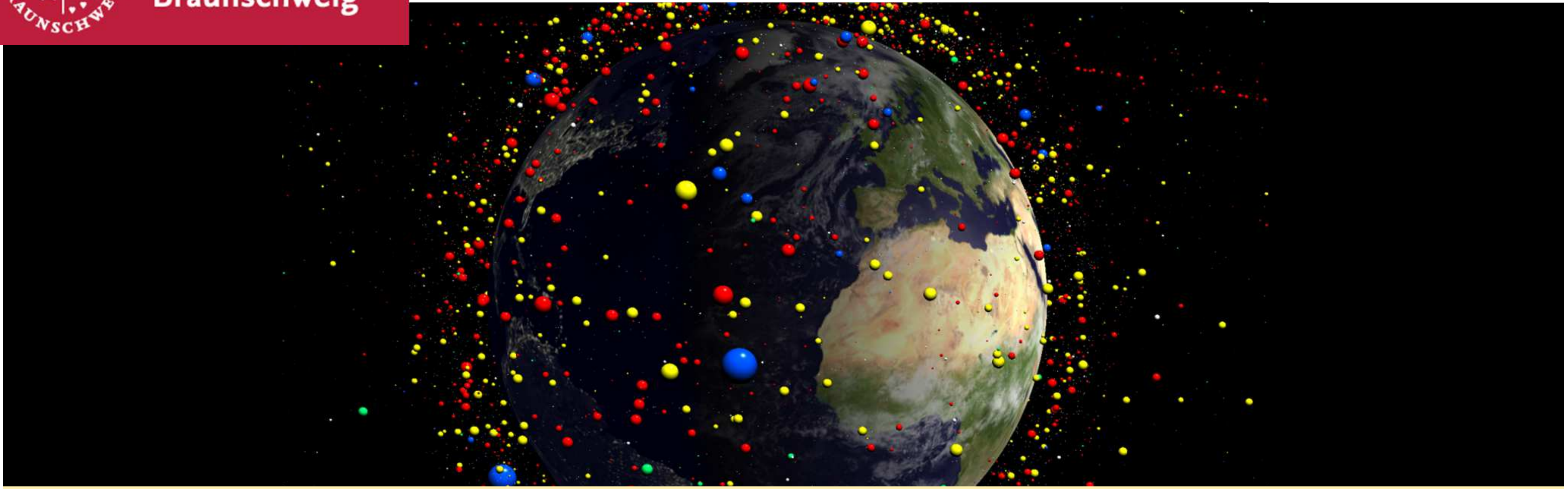

The Economics of Mitigation and Remediation Measures – Preliminary Results

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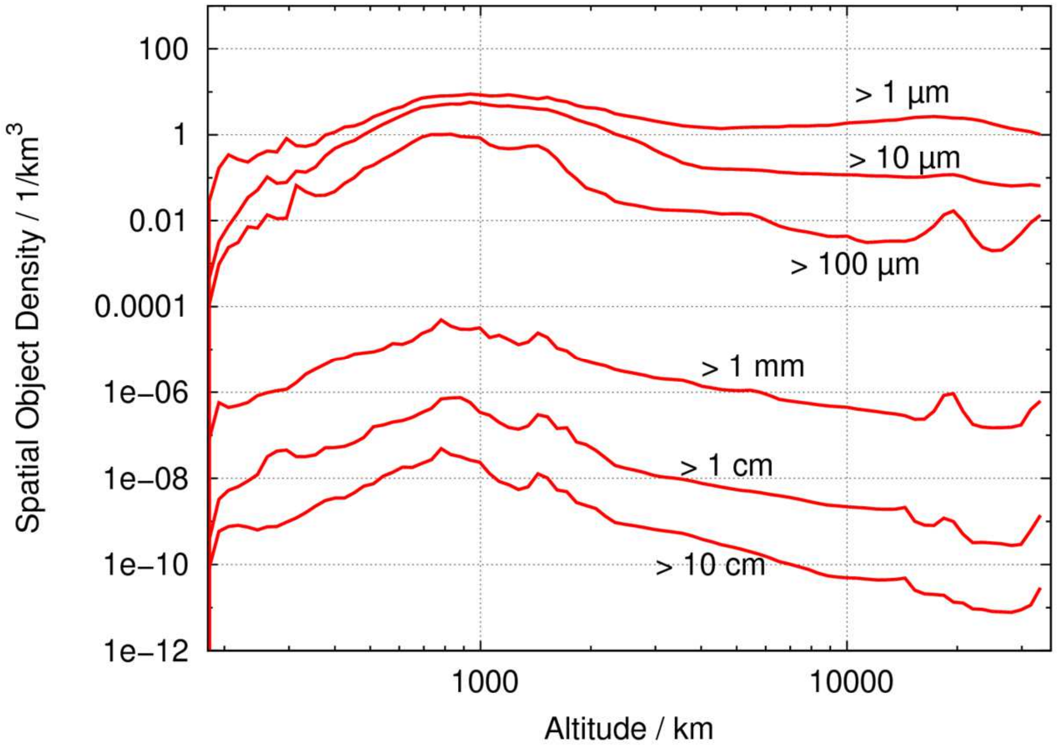
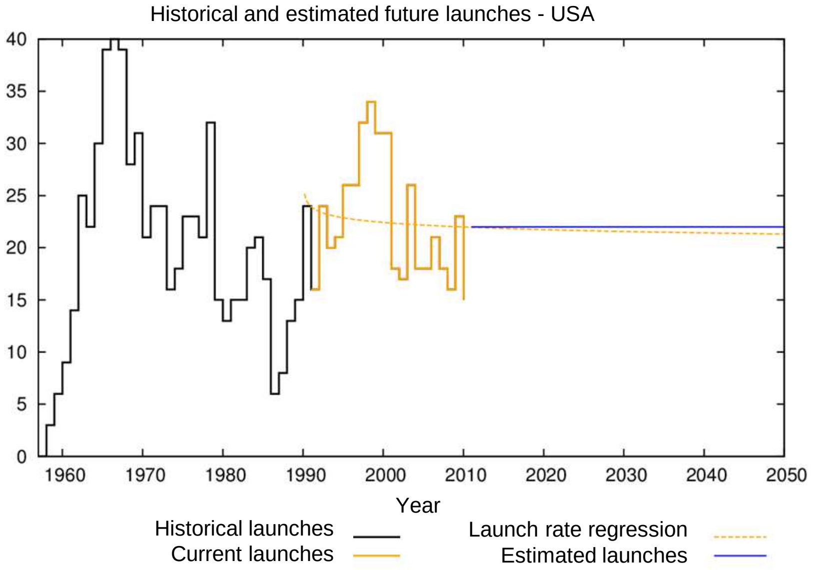
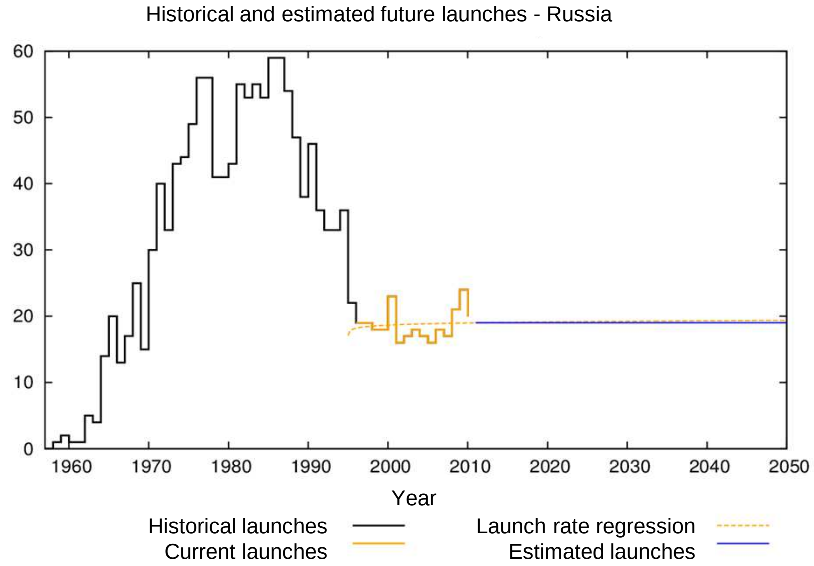
Introduction

Today there exists a high spatial density of orbital debris objects at about 800 km altitude. The control of the debris population in this region is important for its preservation.

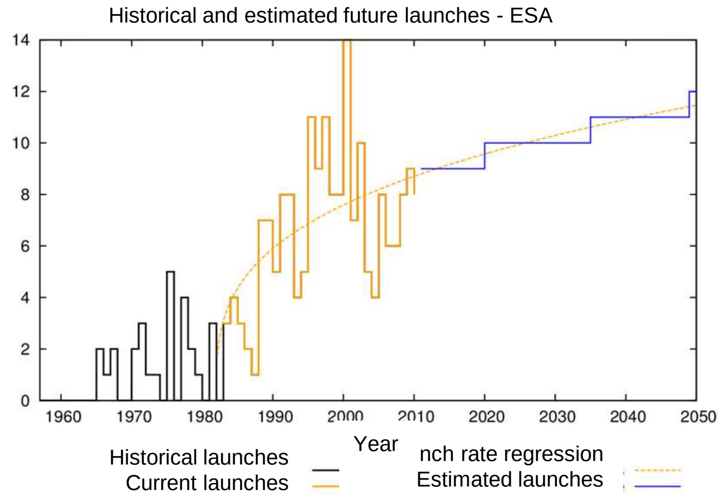


Definition of the BAU Scenario: Launch Rates

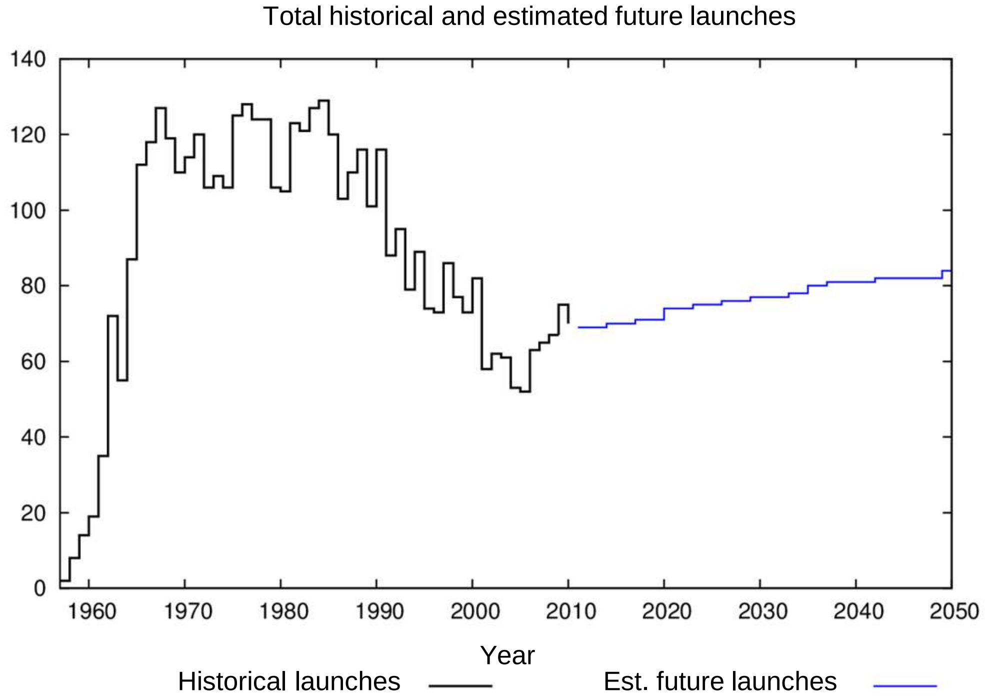




- Constant launch rates for USA and Russia
- Increasing launch rates for ESA, China, Japan, India and Israel



Definition of the BAU Scenario: Total Launch Rate



- Total estimate: Slightly increasing launch rate
- Approx. 67 to 83 annual launches between 2012 and 2050

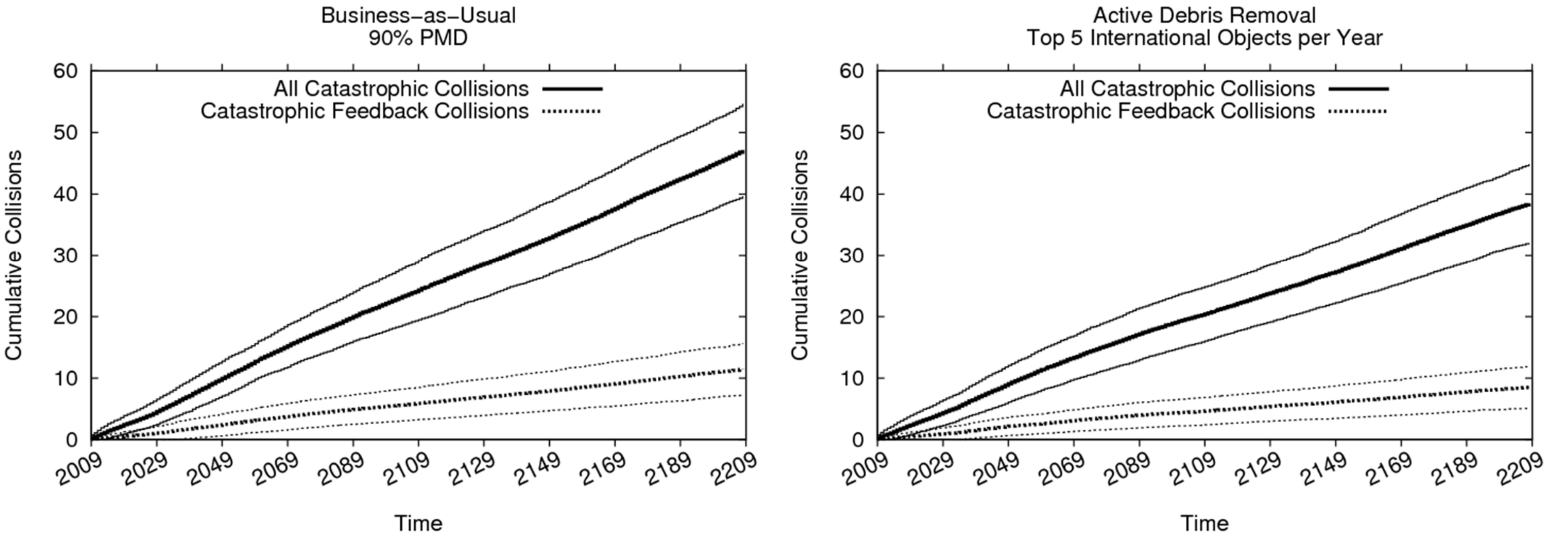
- Based on MASTER-2009 population data
- Satellite life time of seven years
- Two explosion events per year
- Post-Mission Disposal (PMD) to a 25 year orbit (success rate: 90%)

Active Removal Scenarios: Parameters

The simulation of active removal is based on the assumption that a sophisticated service satellite maneuvers a target object to a direct re-entry trajectory. The service satellite will be launched from Earth and maneuver into the orbit of the target object. After a rendezvous and docking maneuver, the service satellite shall perform a controlled re-entry maneuver together with the target object. It is assumed that the service satellite itself is lost during the mission.

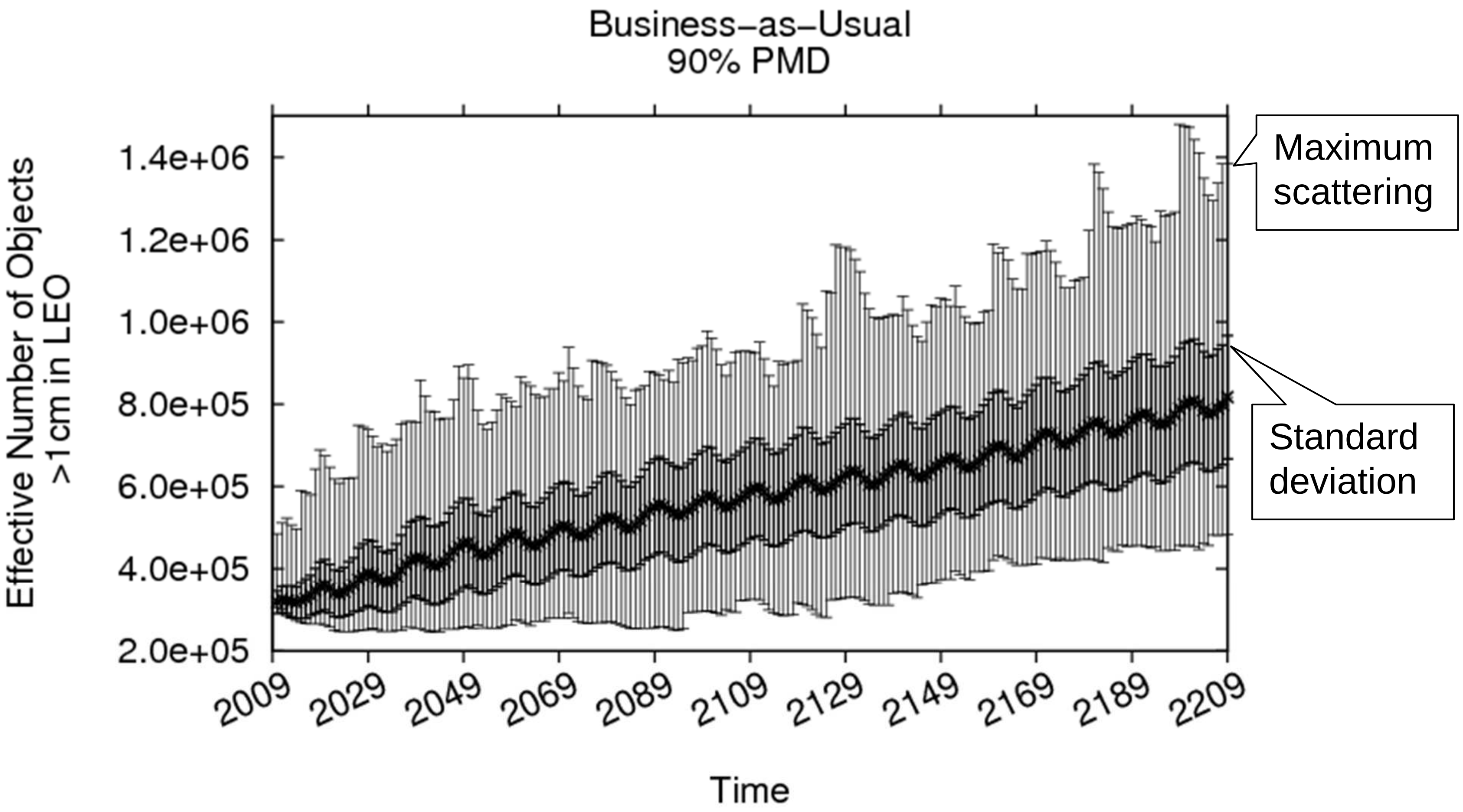
- Based on previously defined BAU scenario (including PMD)
- Newly launched objects with similar properties to existing ones
- Active Debris Removal (ADR) of five objects per year
- Priority list for dangerous objects based on mass, orbit and object flux

Future Catastrophic Collisions



If at least one of the collision objects is the product of a previous collision, one speaks of a “feedback collision”.

Long-Term Simulation



LUCA (Long-Term Orbit Utilization Collision Analysis)

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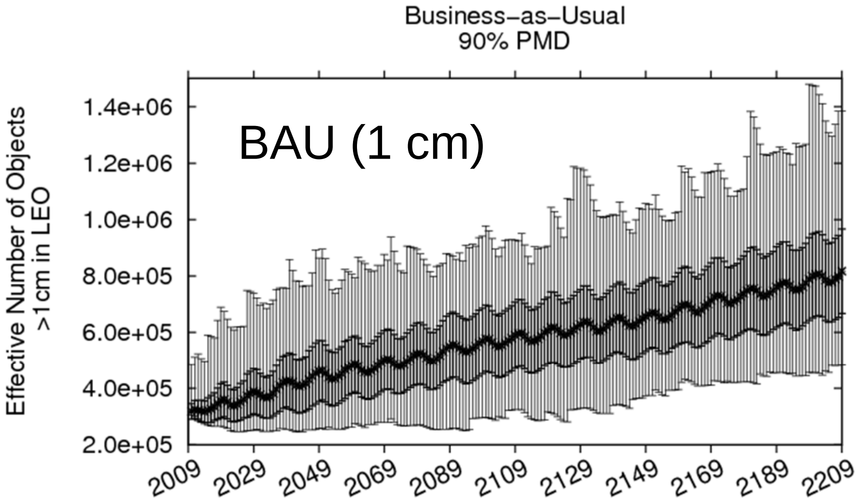
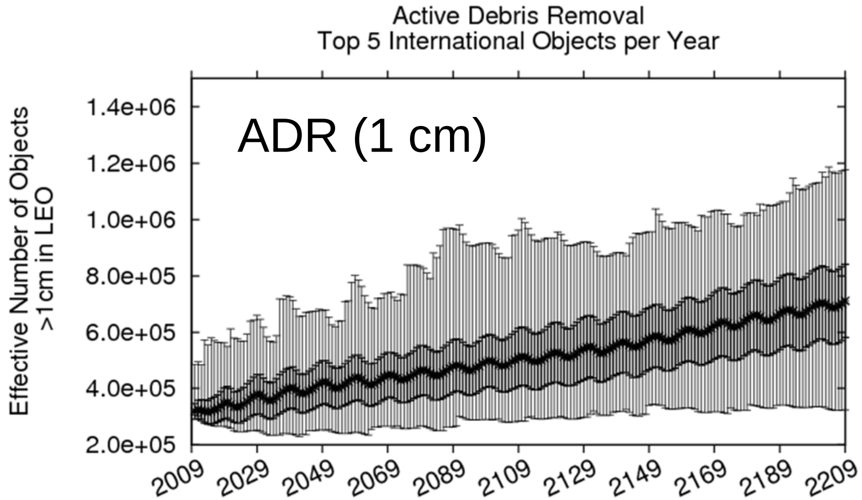
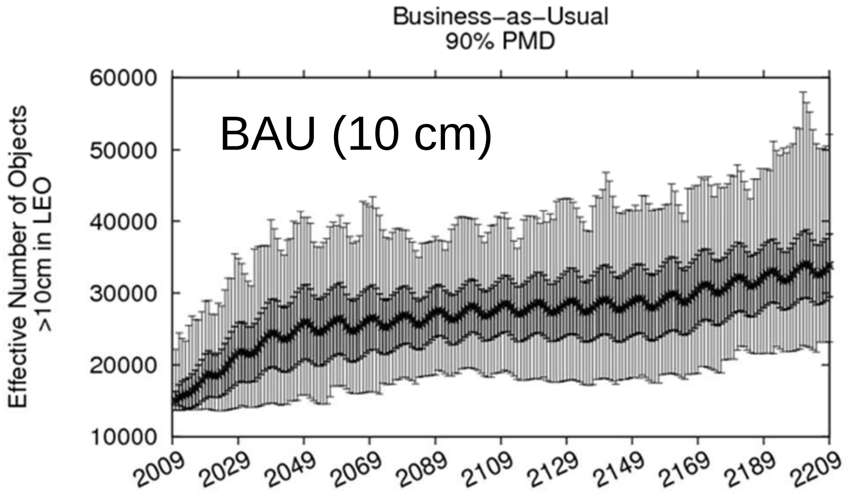
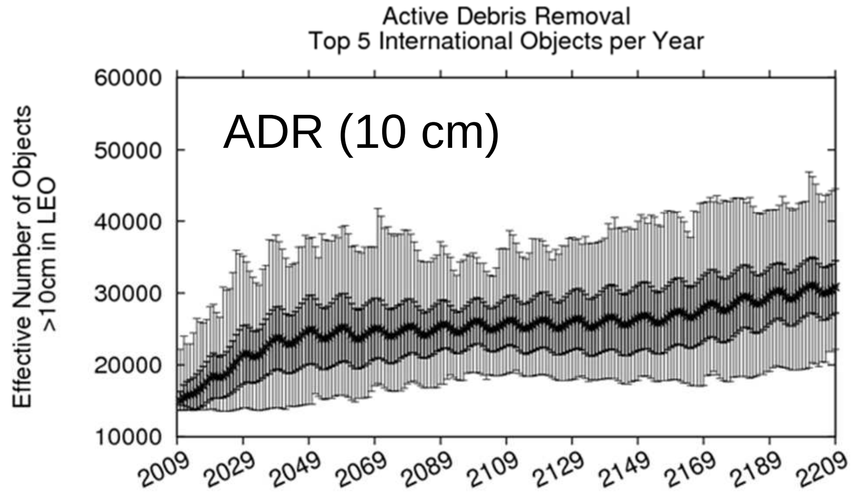
Future Population with Active Removal (1)





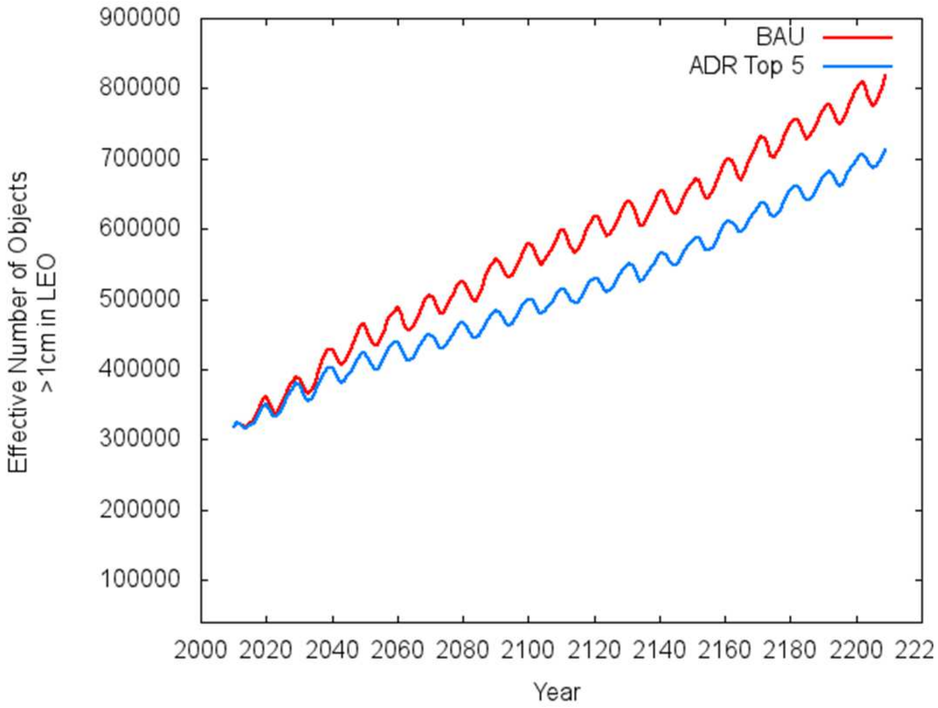




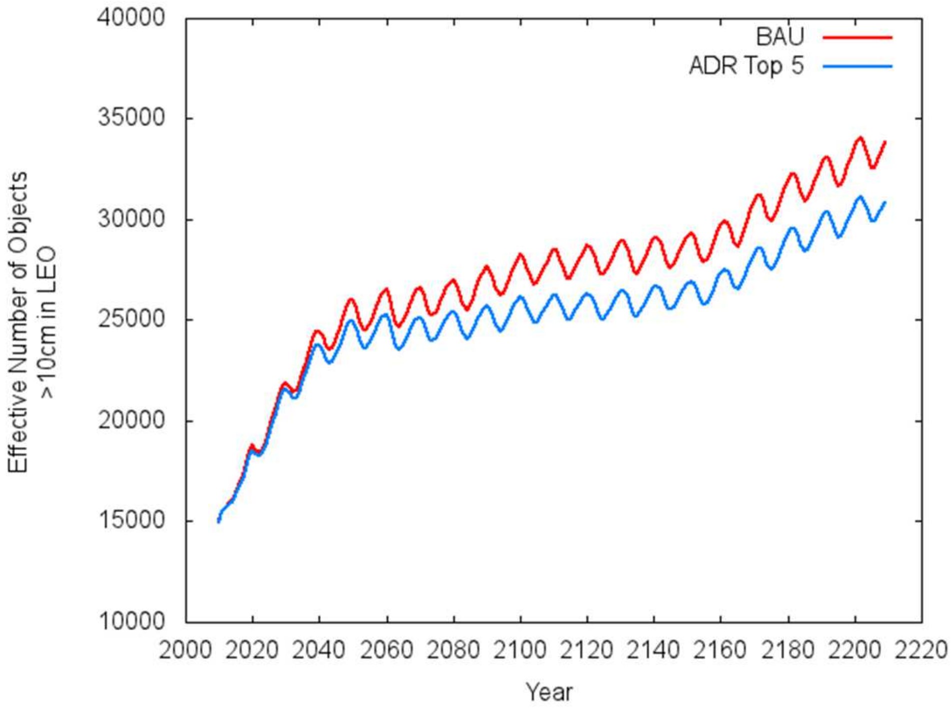
Future Population with Active Removal (2)

Future Population

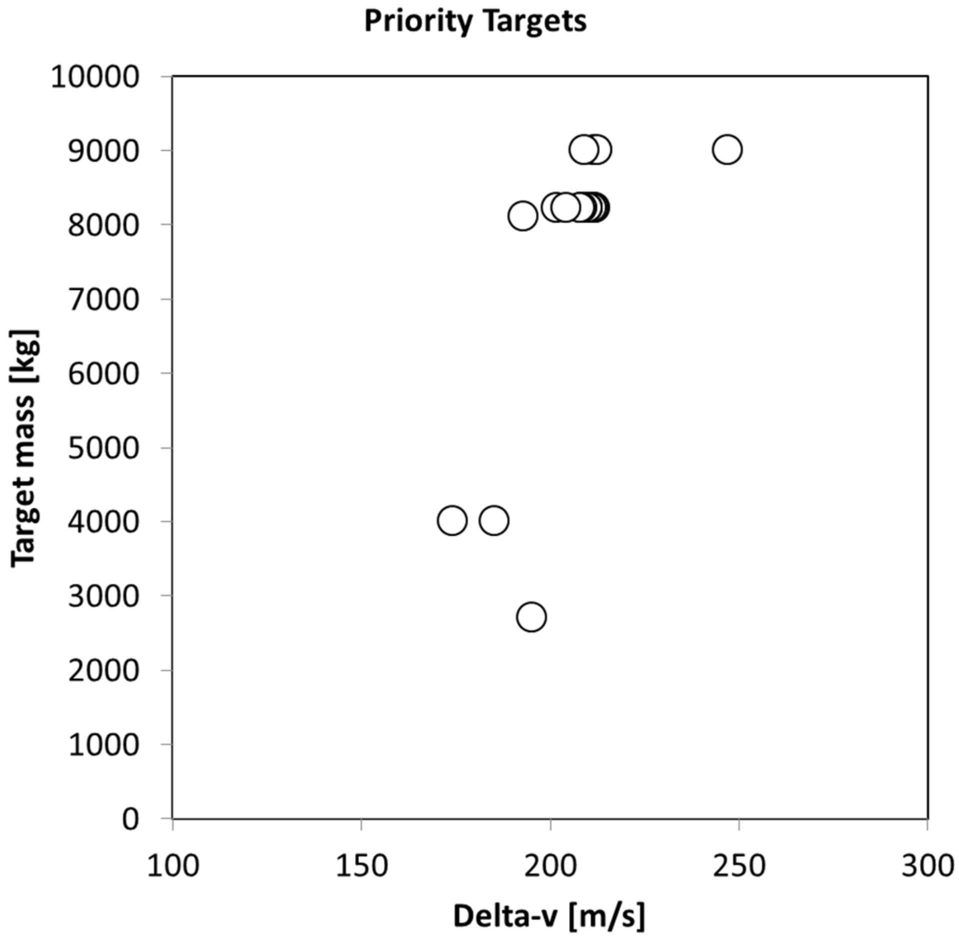
Objects > 1 cm



Objects > 10 cm



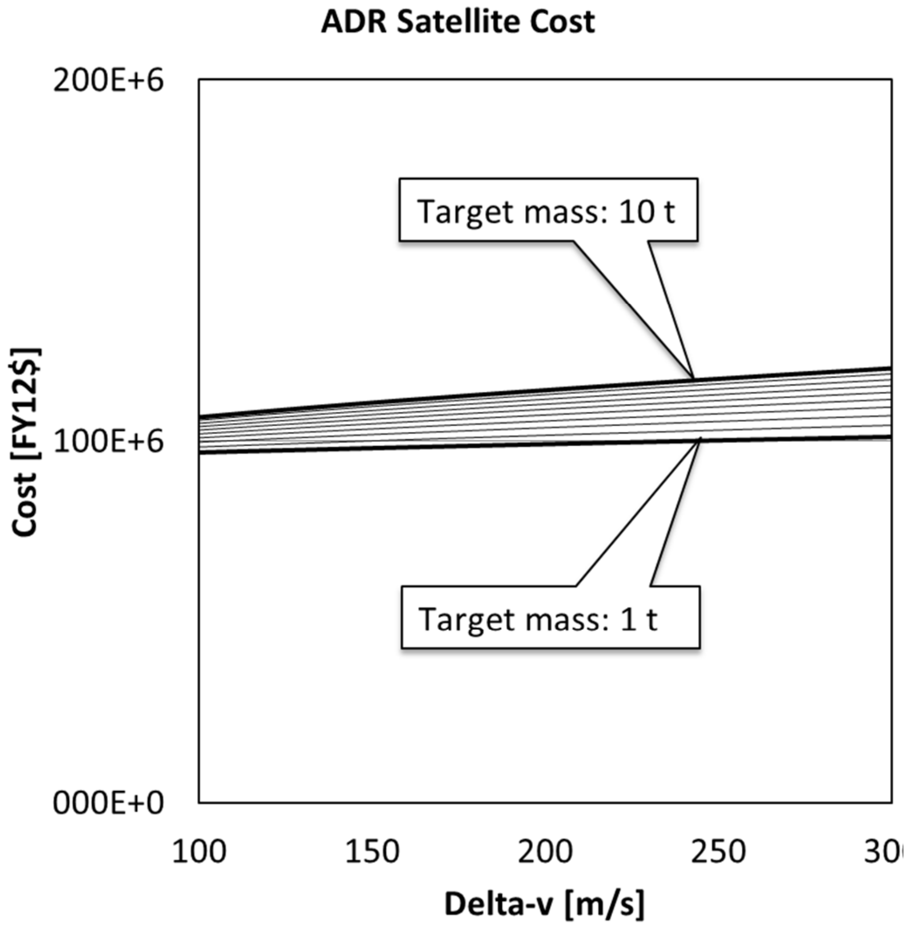
Priority Targets

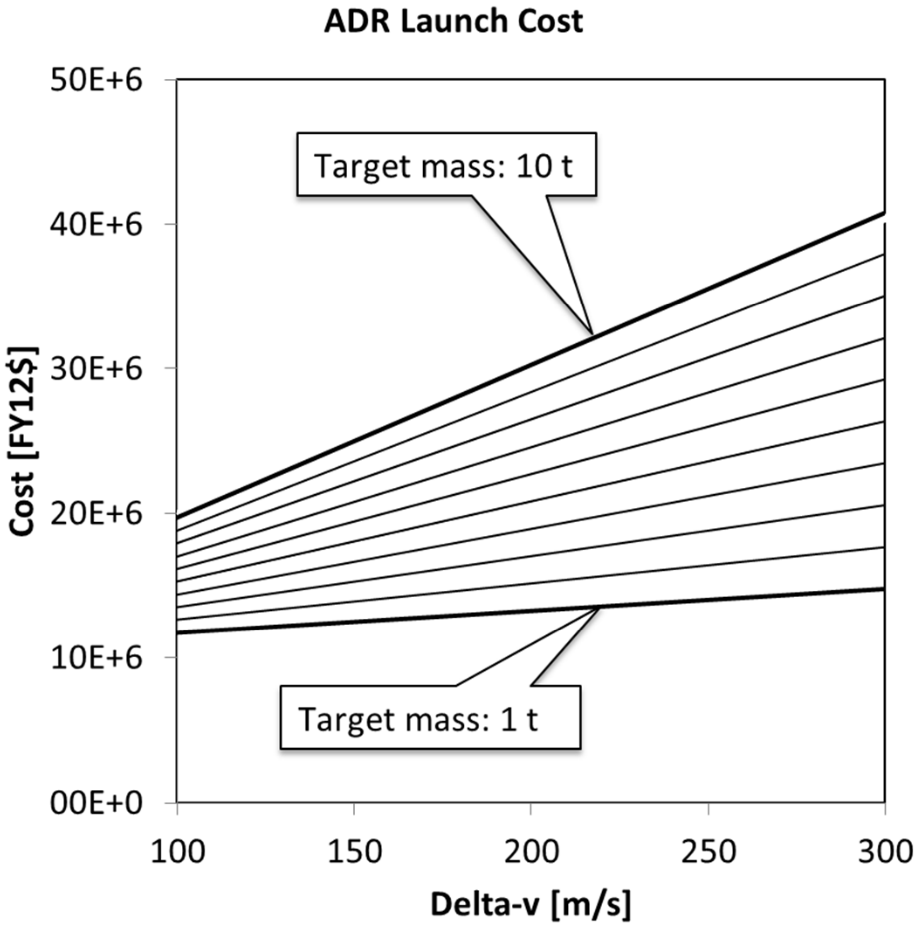


A maneuver is performed that lowers the perigee to 80 km. This allows the direct atmospheric re-entry of the target object along with the service satellite.

The target object has to be selected from the priority list, resulting in a specific fuel requirement for each selected target.

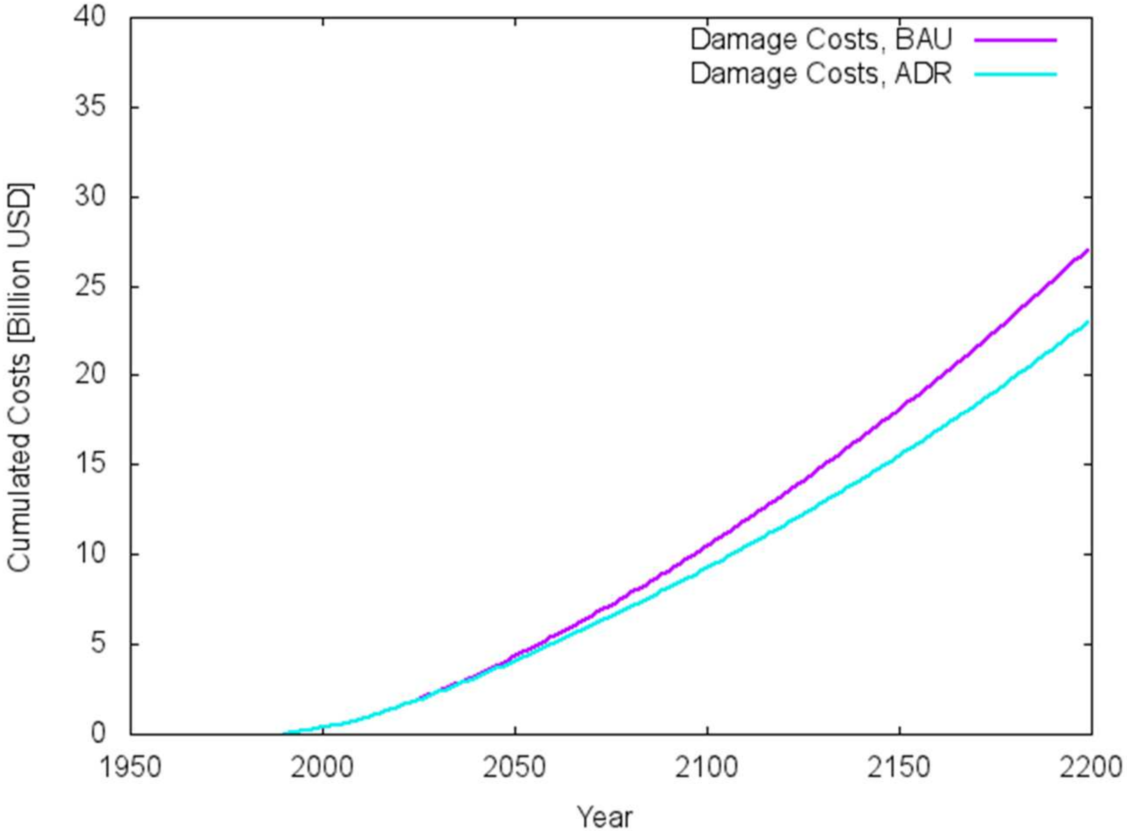
Active Debris Removal: Cost Estimation





Cost Estimations: Damage Cost

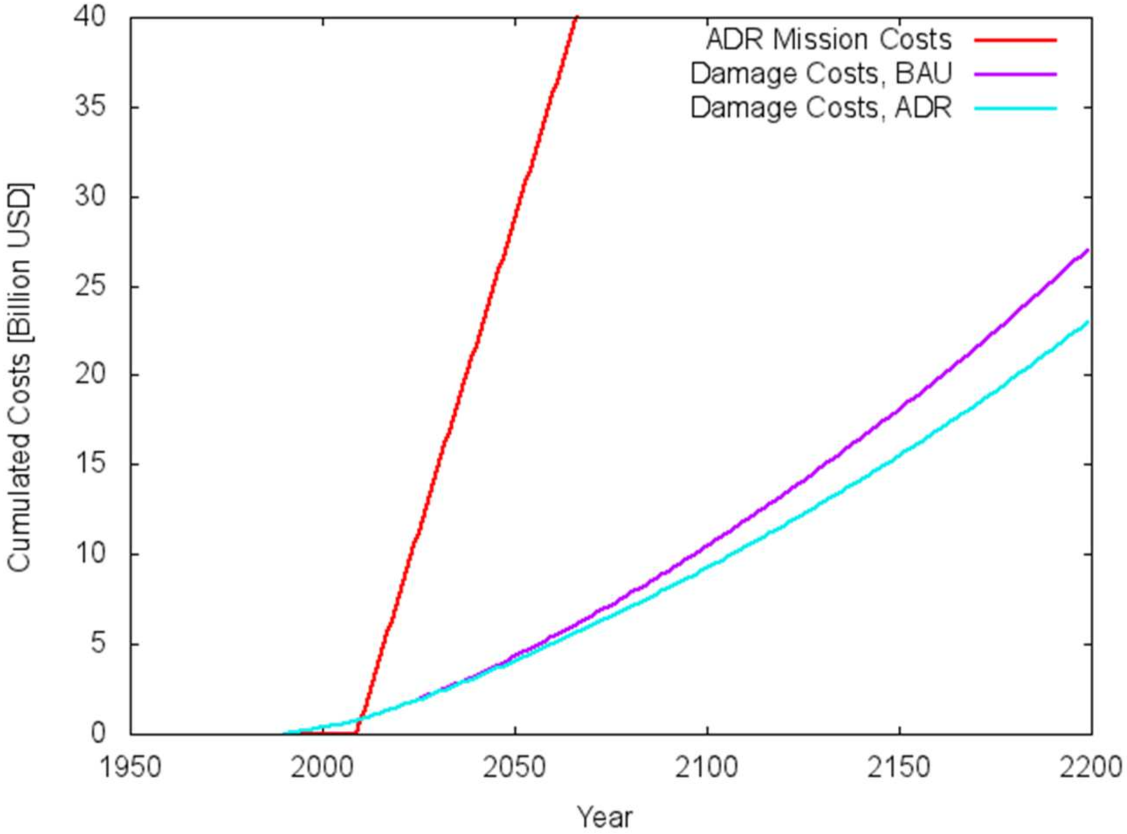
- Every satellite which is hit by an object greater than 1cm has a failure probability of 100 %. This causes cost of lost amortization.
- Calculated for active satellites in LEO.
- Failure probability derived from MASTER-2009 object flux.
- Slight reduction of damage costs with ADR.



The number of impacts is controlled by the traffic model and the mitigation measures. Thus the cumulative damage cost is different for each mitigation scenario.

Cost Estimations: Active Debris Removal

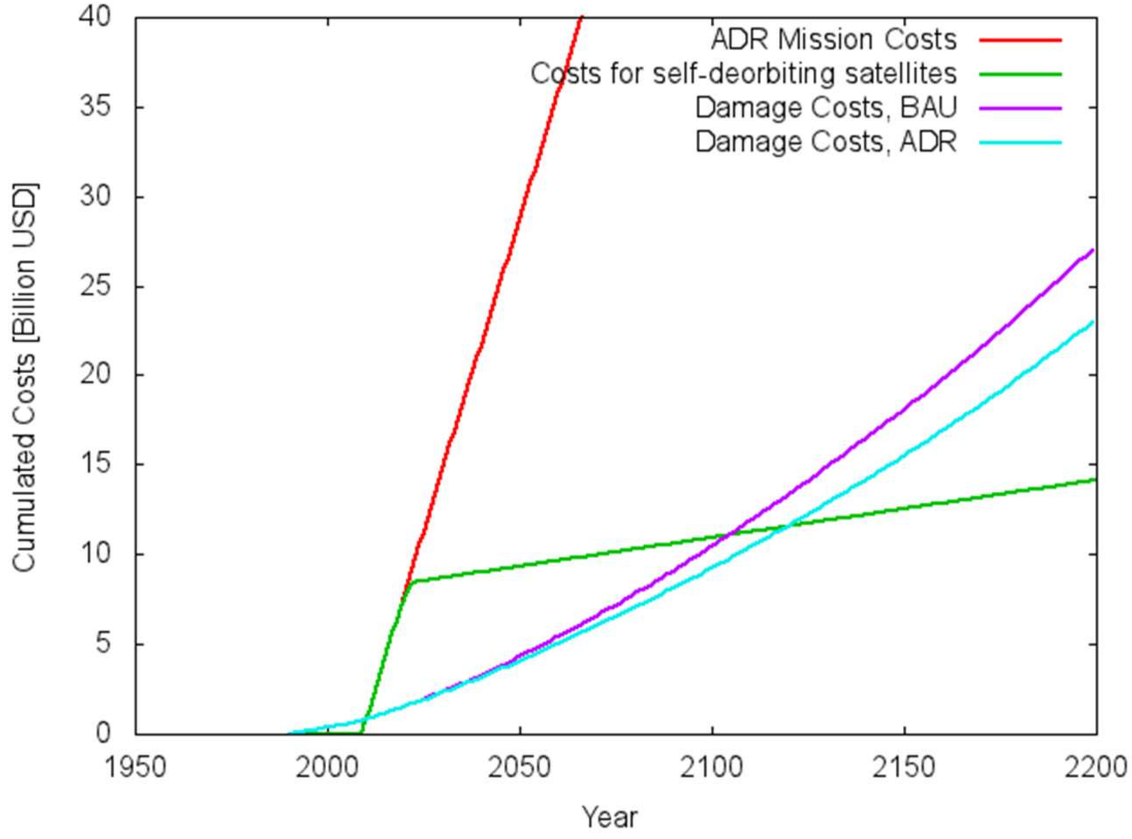
- Costs for ADR missions outweigh financial benefit
- Estimated cost of active removal missions: 140 Million USD per satellite (700 million USD per year)



Cost Estimations: ADR & De-Orbiting

- Costs can be greatly reduced by equipping new satellites with de-orbiting motors after a few active removal missions

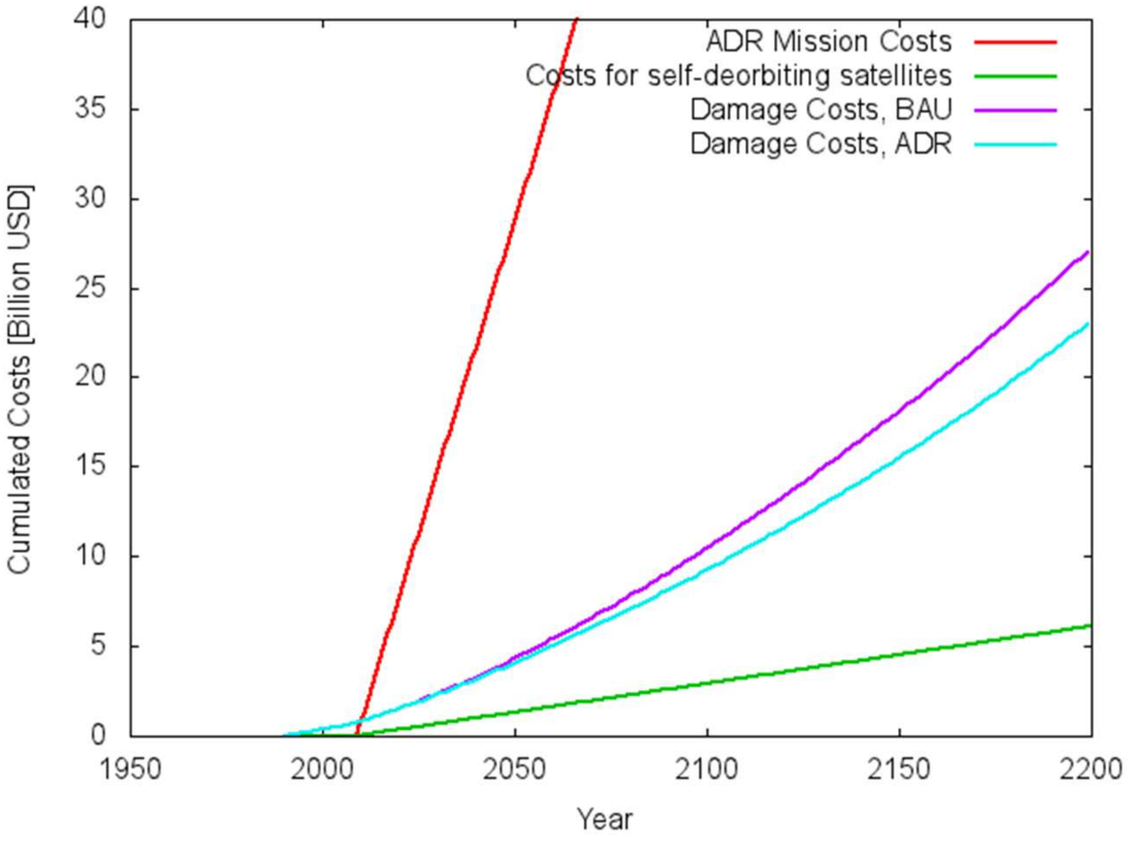
- Controlled de-orbiting of 5 priority targets per year.



Cost Estimations: De-Orbiting

- Costs would be even lower if today's LEO satellites would have been equipped with de-orbiting motors

- Estimated additional cost of de-orbiting satellite (controlled re-entry): 6.4 Million USD per satellite (32 million USD per year)



Summary

- A realistic BAU scenario considering political and technical trends is developed.
- Long-term simulations confirm that the number of debris objects will increase in the future.
- ADR can have a positive influence on the development on the space debris environment.
- It turns out that de-orbiting is much cheaper than a subsequent active removal. De-orbiting is only possible if a propulsion module exists onboard the target object. (In fact, this capability does not exist onboard the historic objects in the priority list.)

Acknowledgement

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