Active Debris Removal

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OPS-GR, ESA/ESOC

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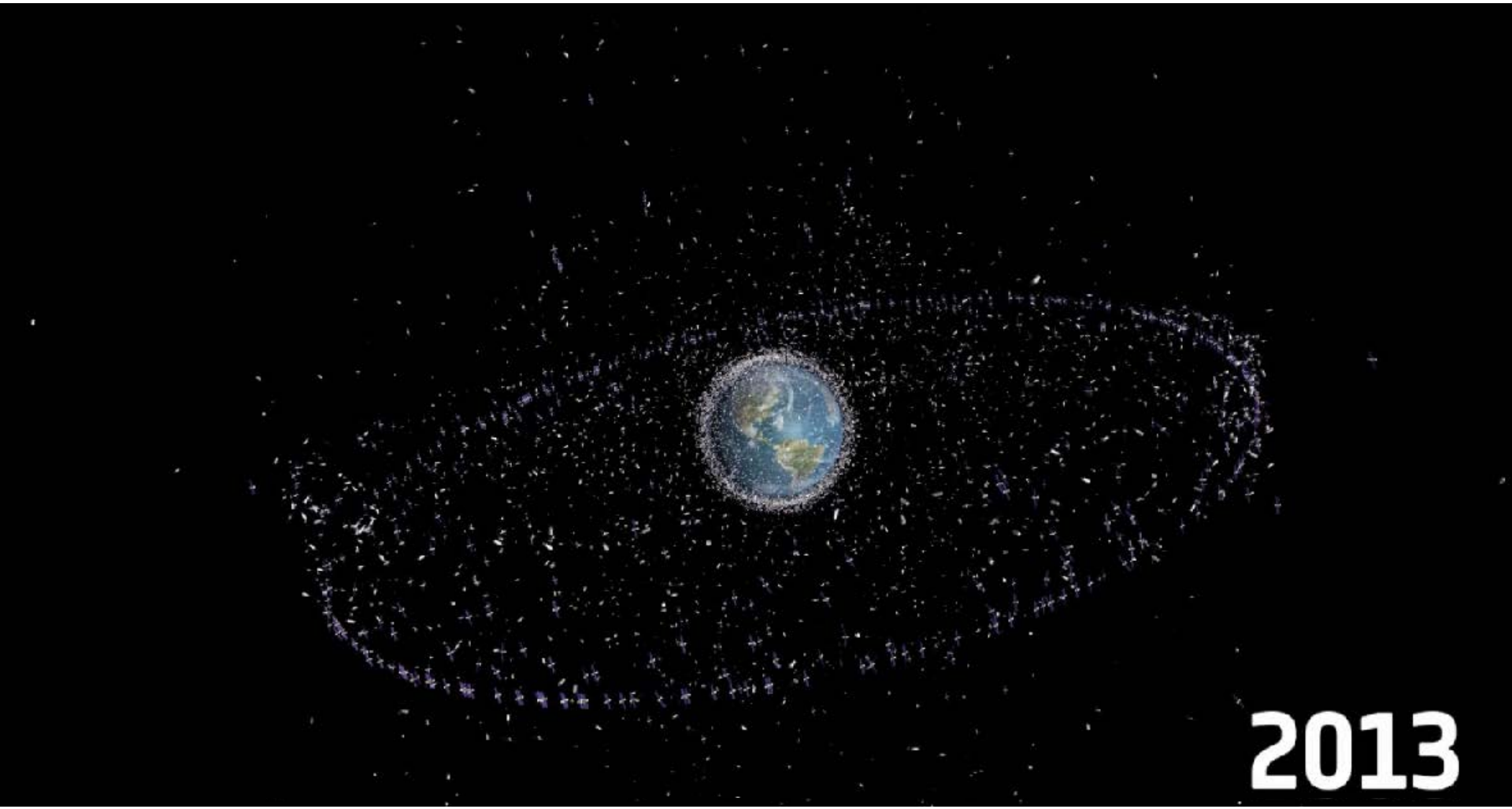
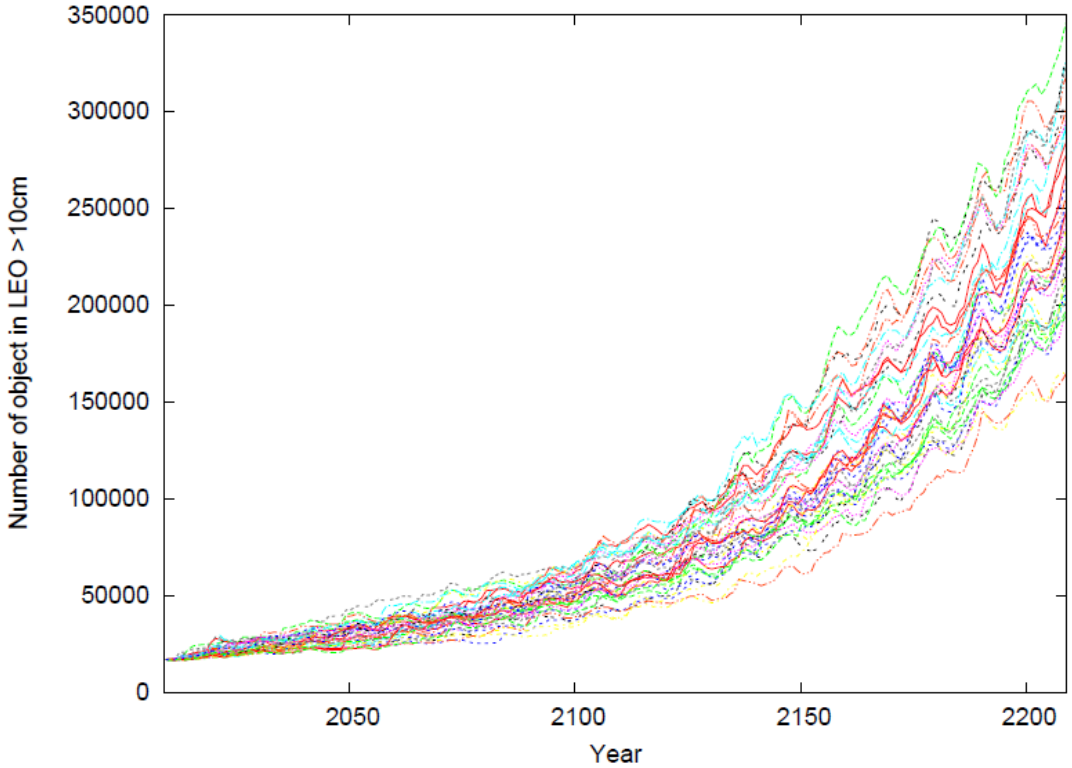
Distribution of Catalogued Objects

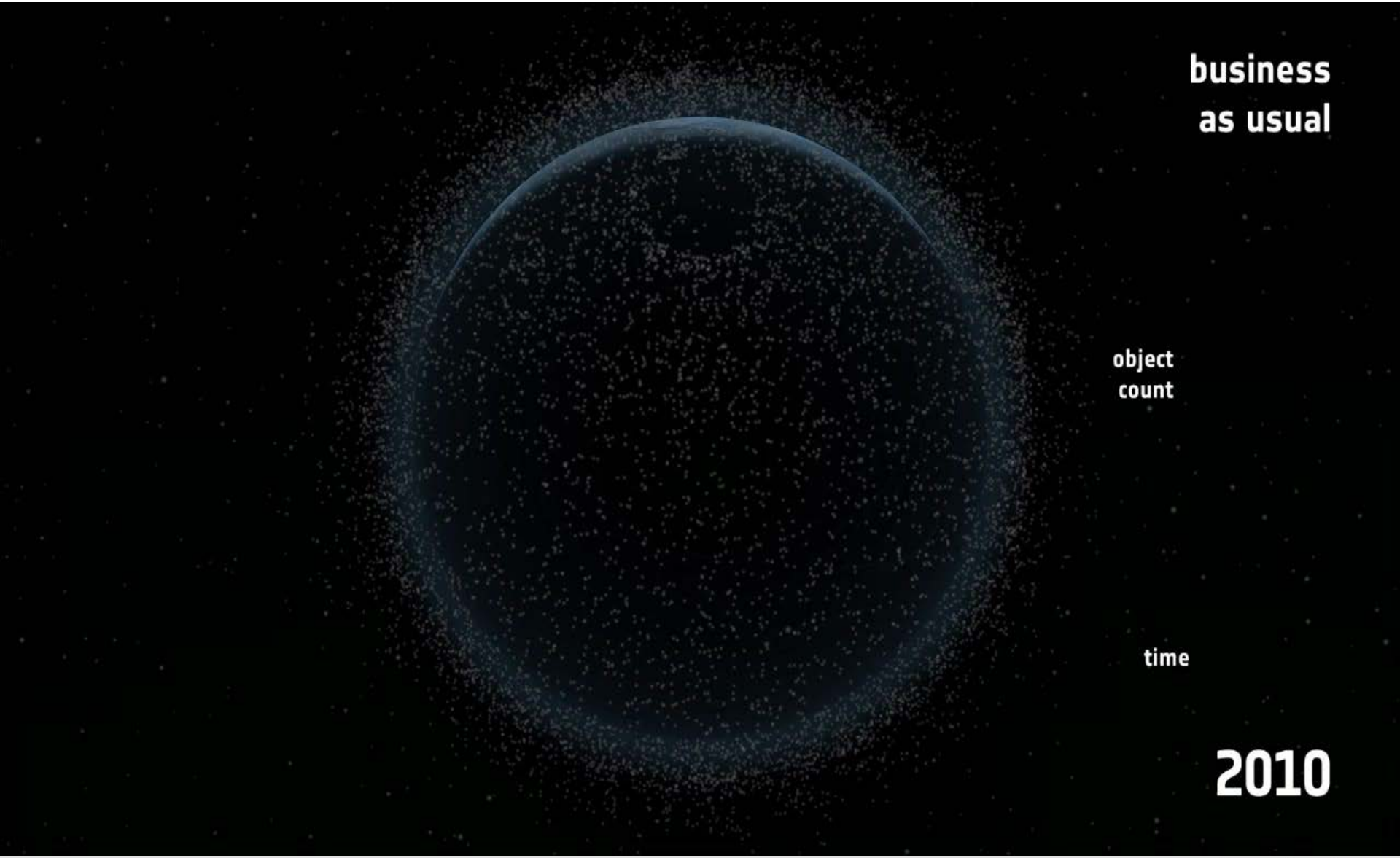


Environment Projections

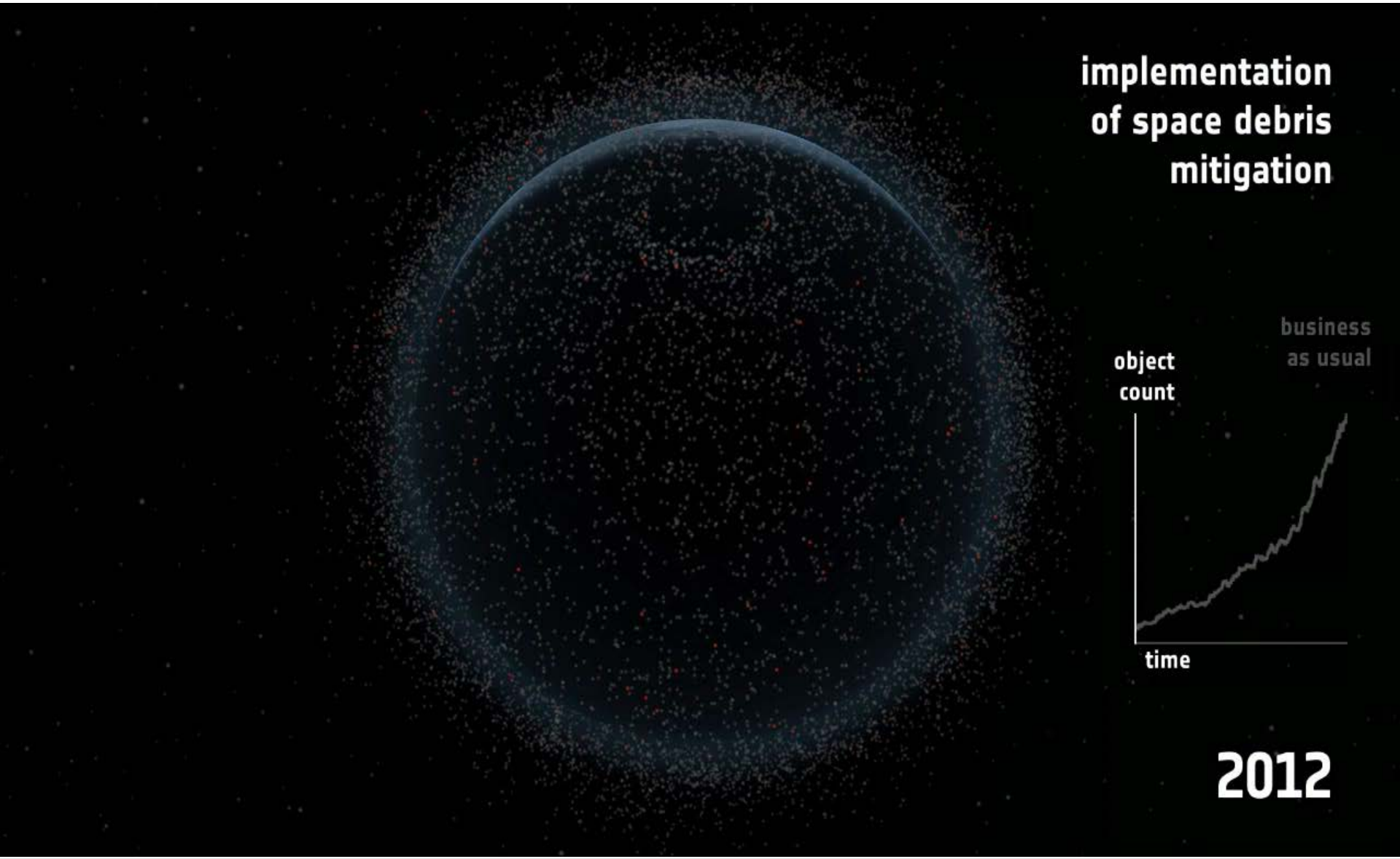
- DELTA: Debris Environment Long-Term Analysis
- 3-D time dependent semi-deterministic model
- Simulation of environment response to mitigation actions
- Traffic Model derived from past 8 years
- Population 10 cm and above
- 40 Monte Carlo Runs



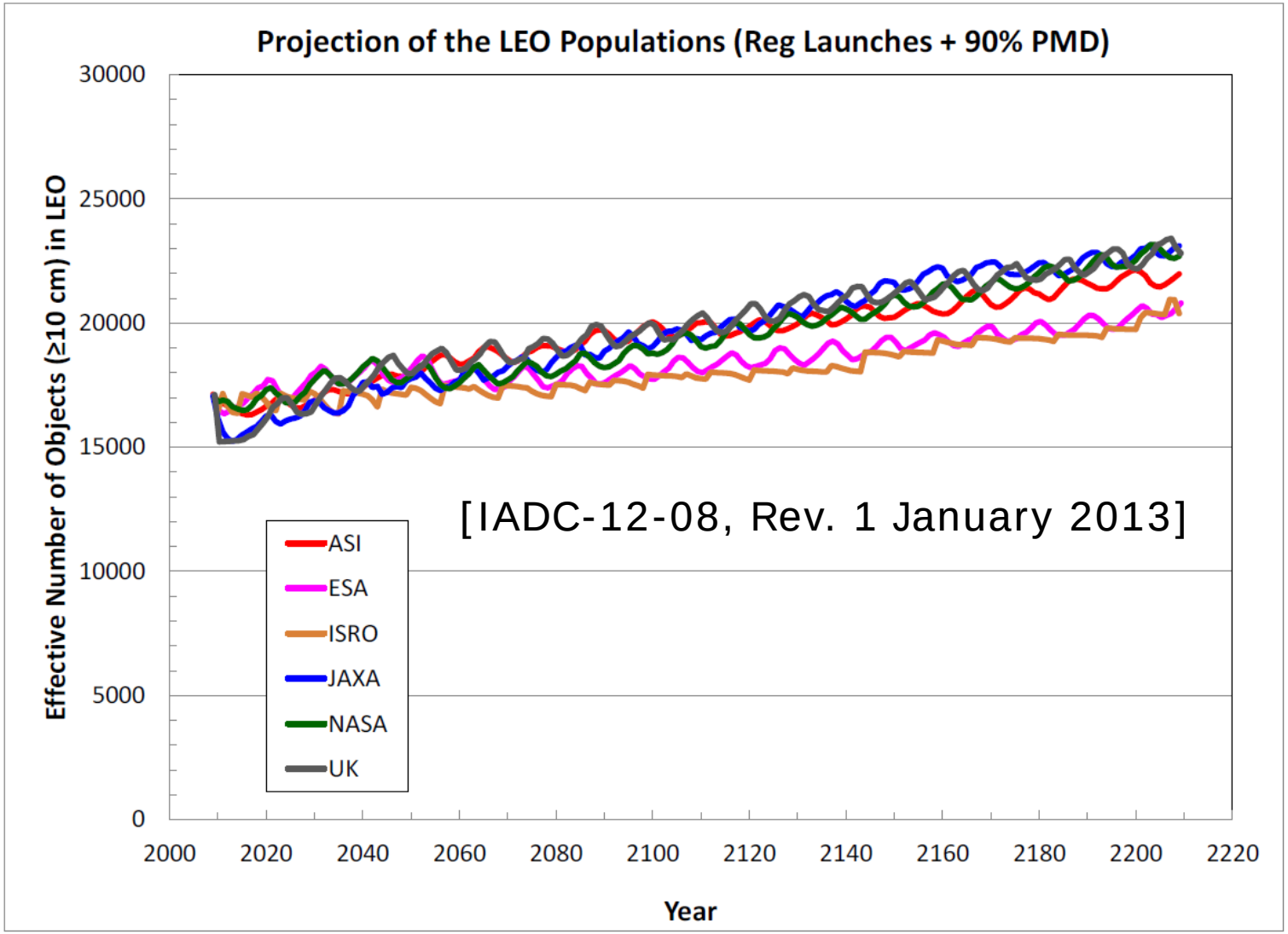
Business As Usual



Mitigation

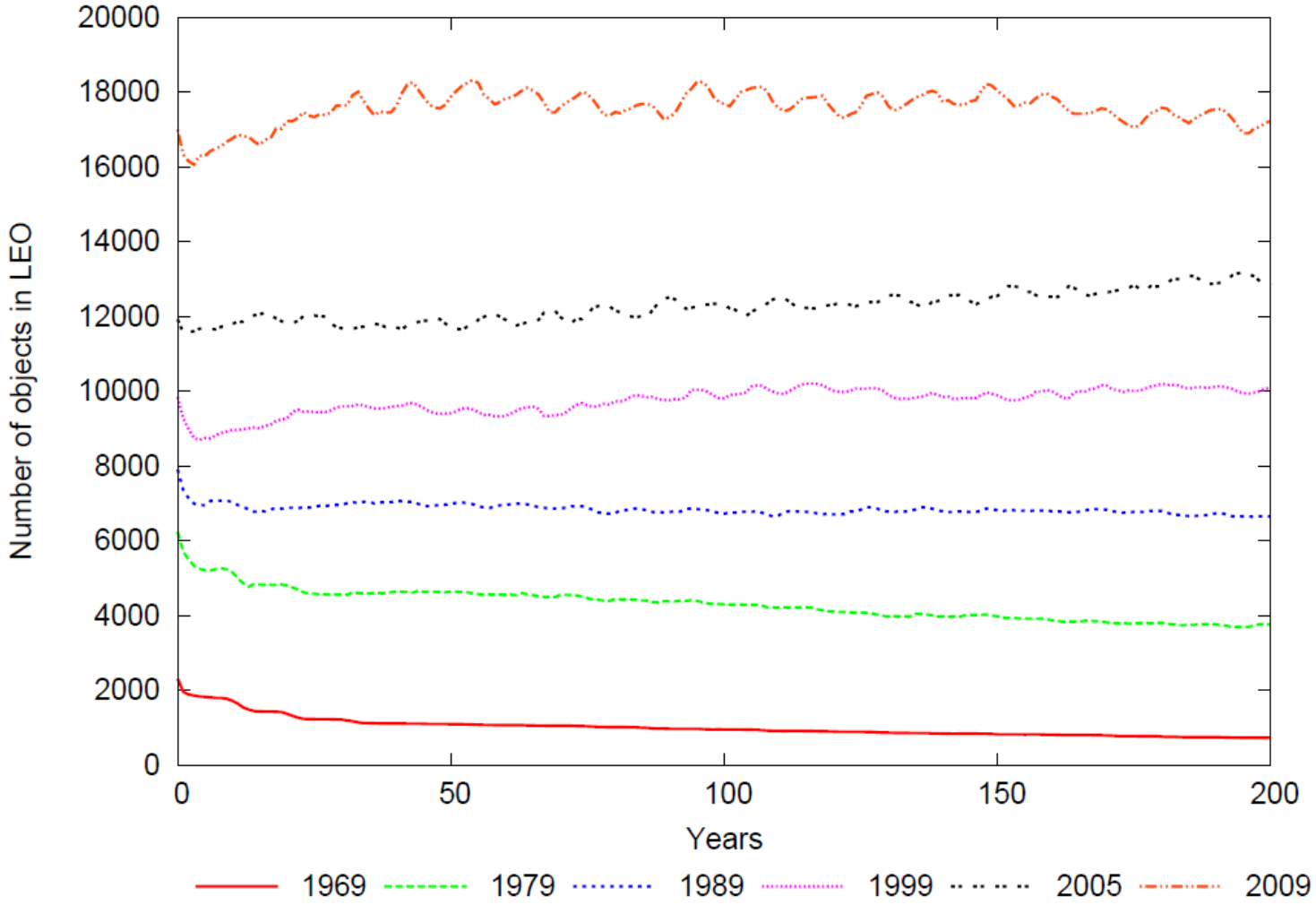

implementation
of space debris
mitigation
business
as usual
object
count
time
2012

Instability of the Current Environment in LEO

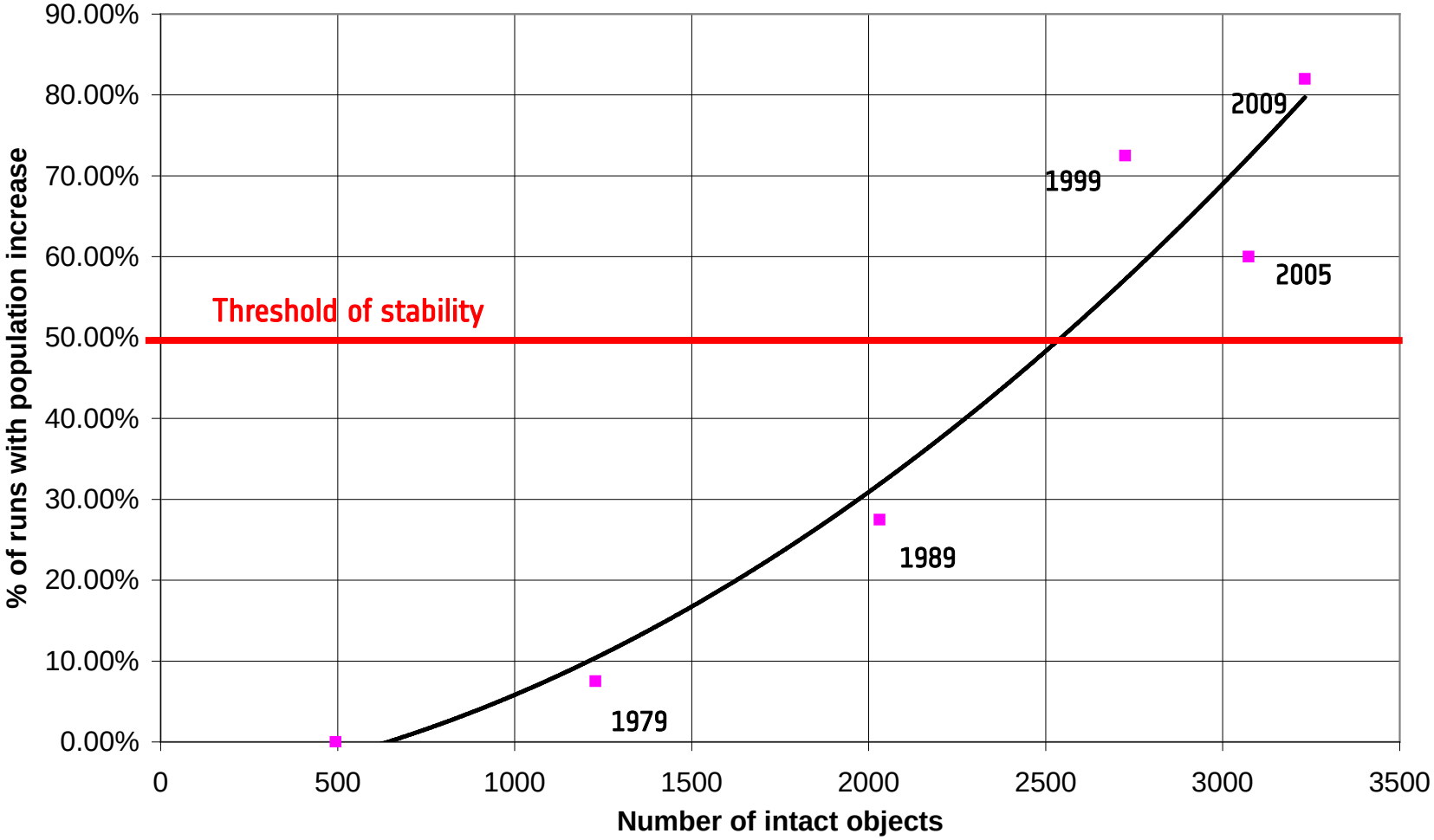


Analysis of Different Historical Populations

– Historic initial populations at different epochs from MASTER



Stability of Historical Populations



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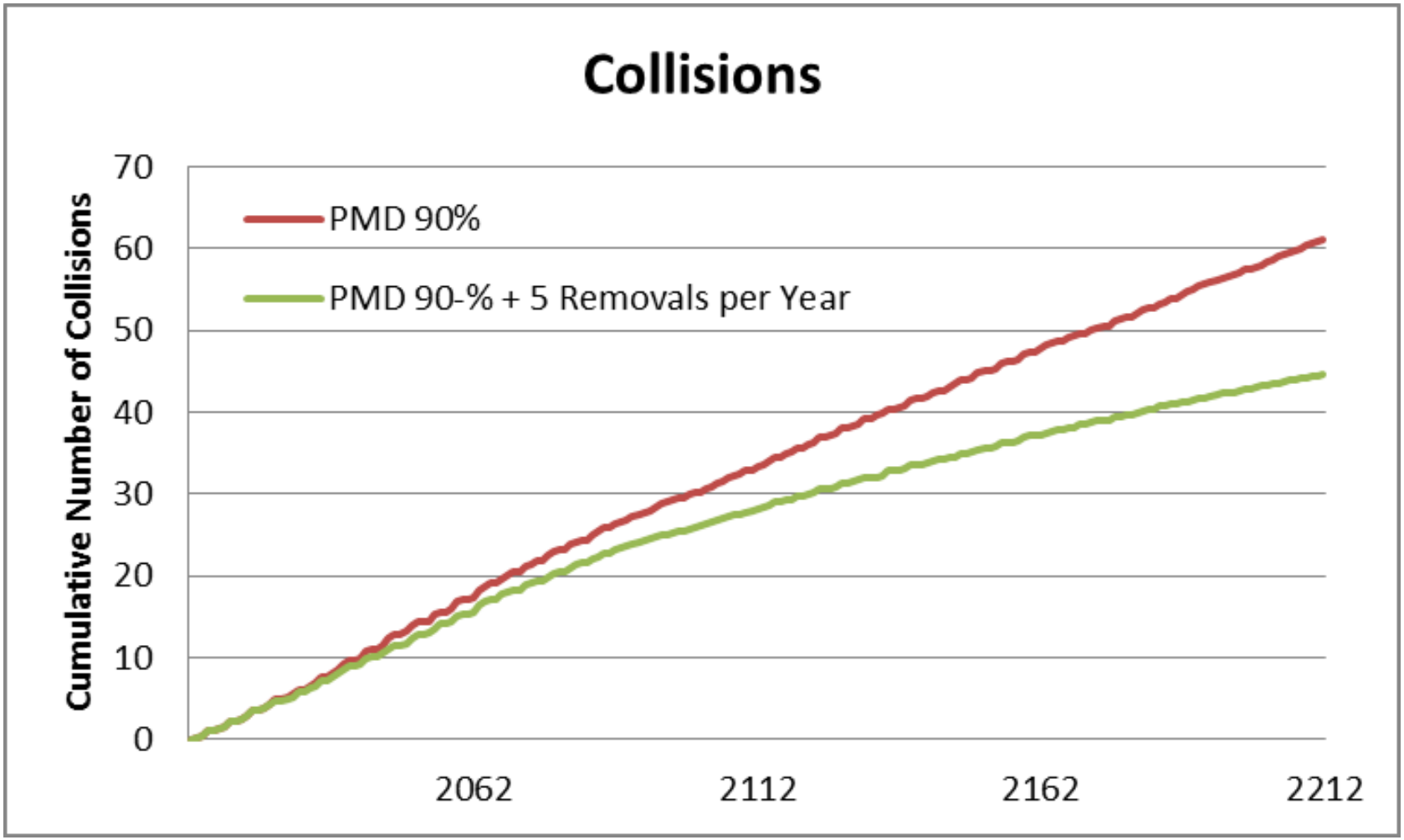
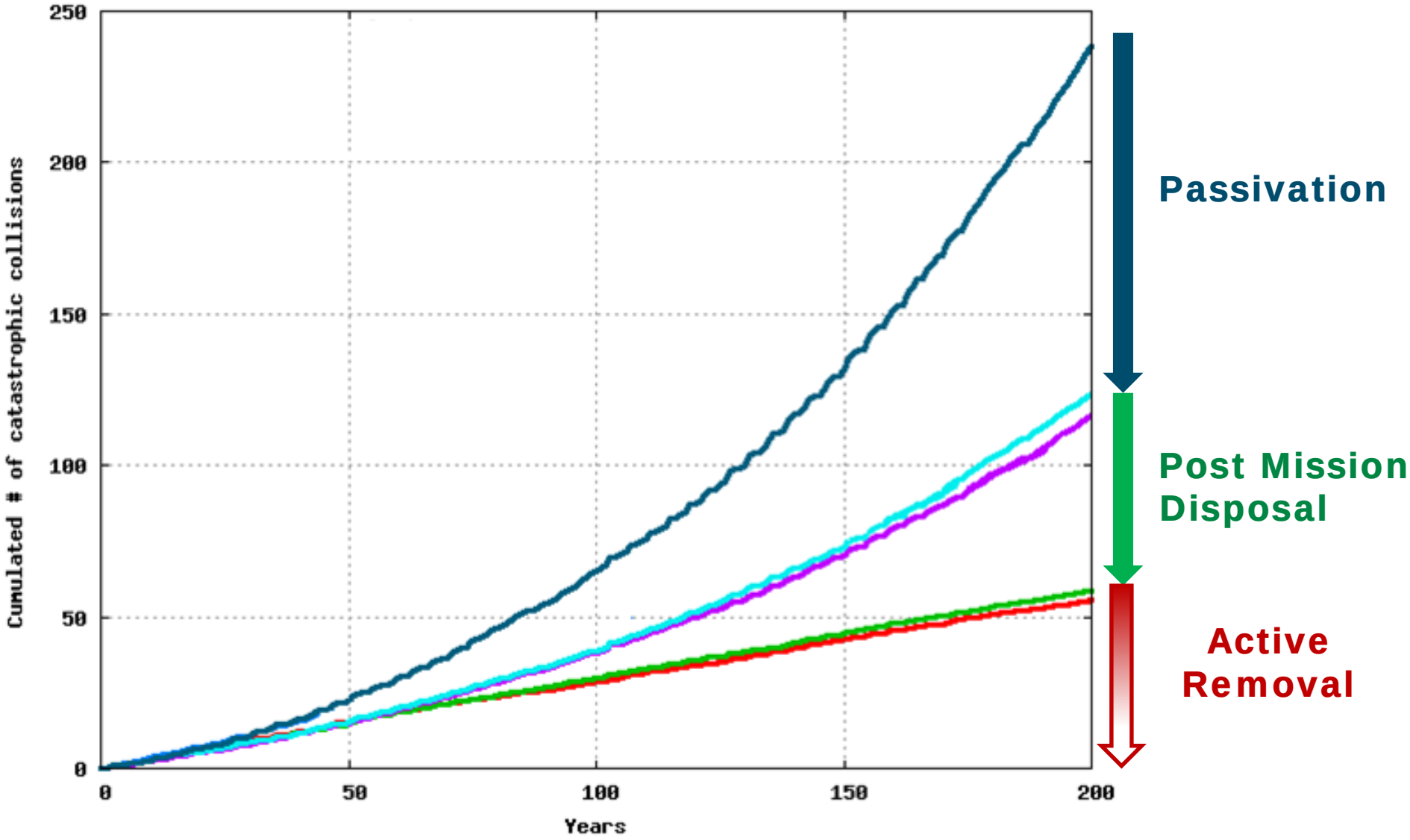
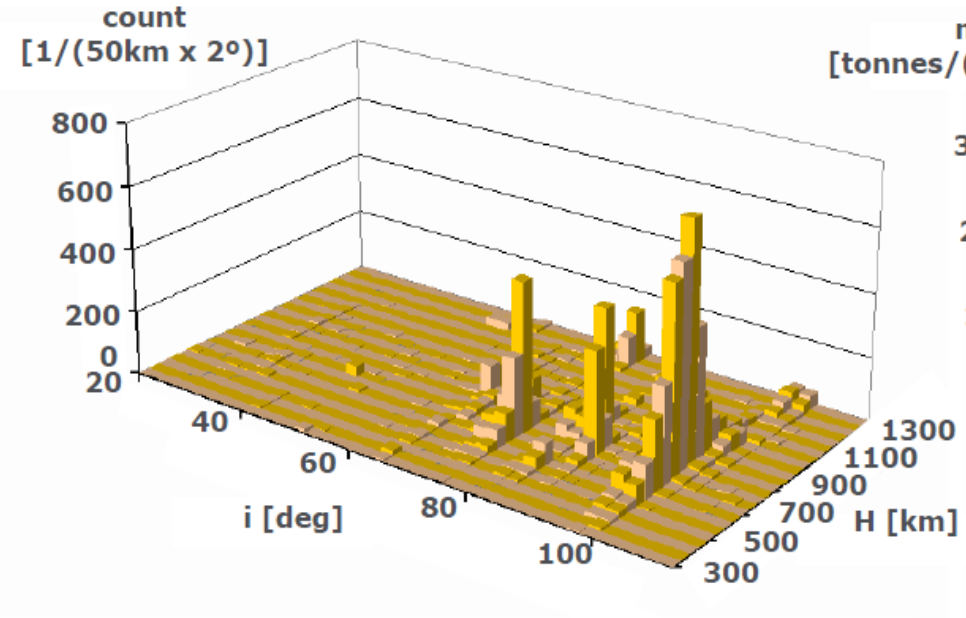
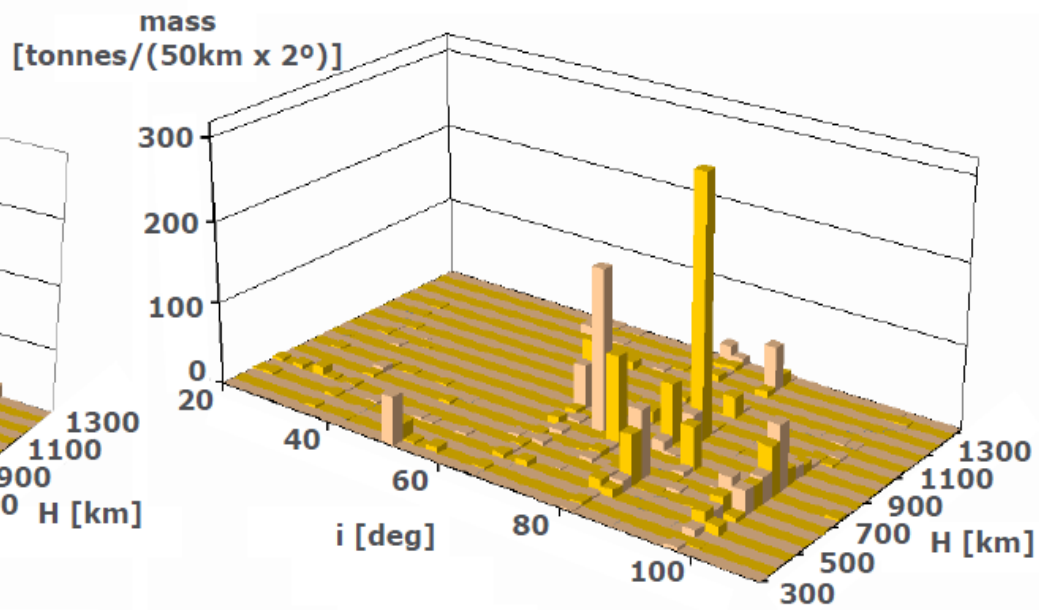


The Role of Active Removal



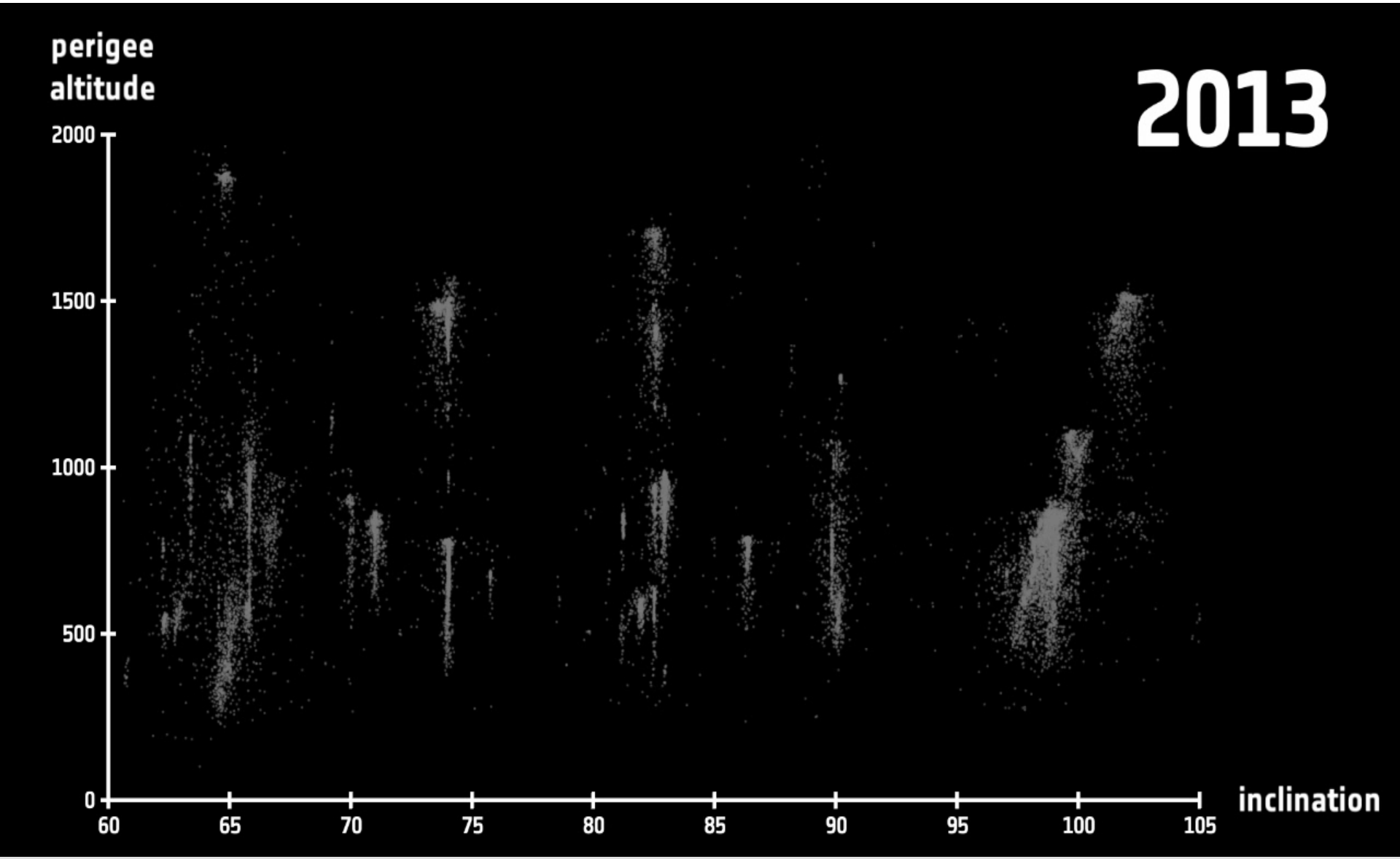
Object Mass and Distribution in LEO



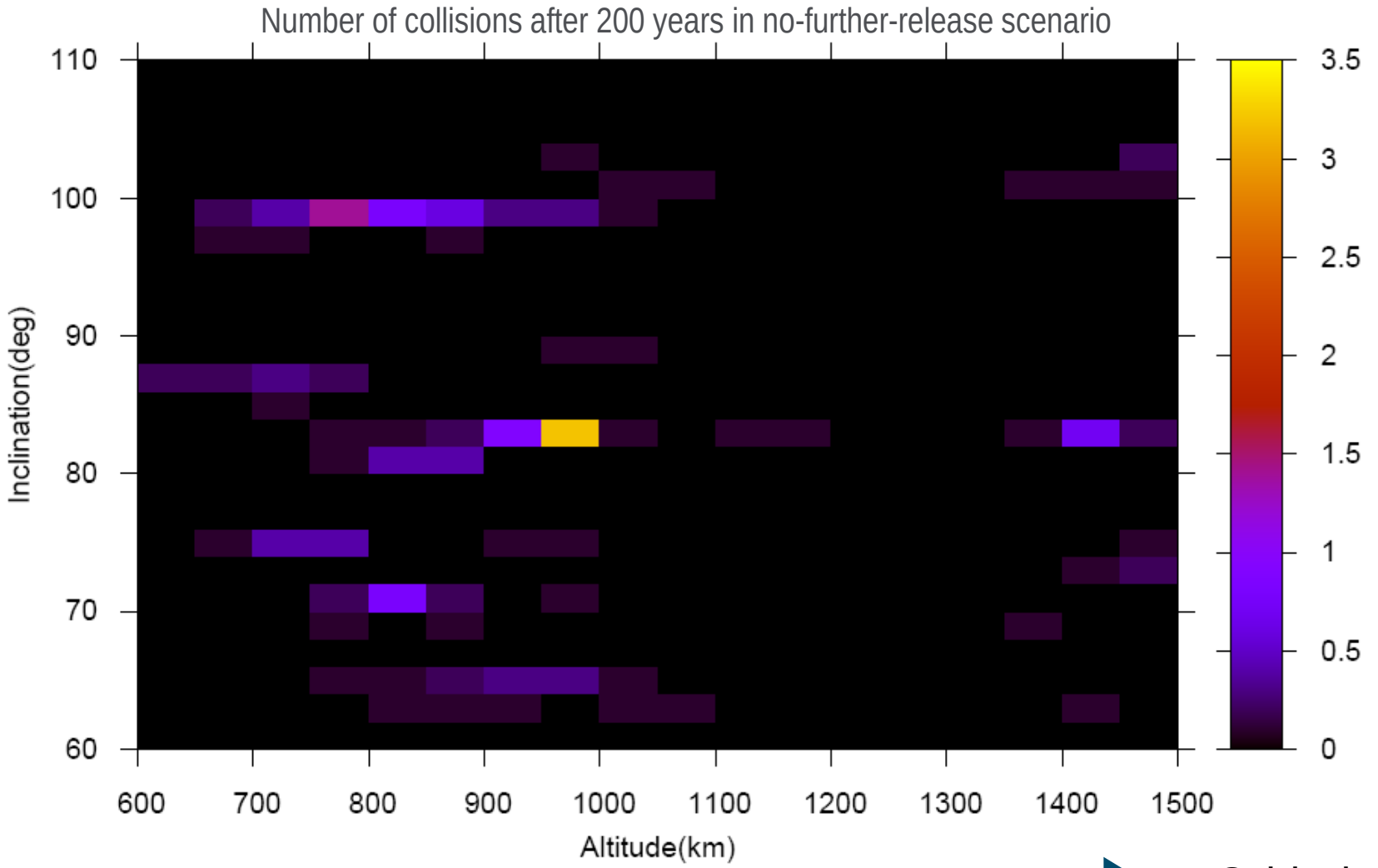


- Characteristics of the LEO environment
  - Only 0.3% of the volume from 120km to super-GEO altitudes
  - 77% of the catalogue population
  - 40% of the on-orbit mass

Orbital Regions of Interest (1/2)

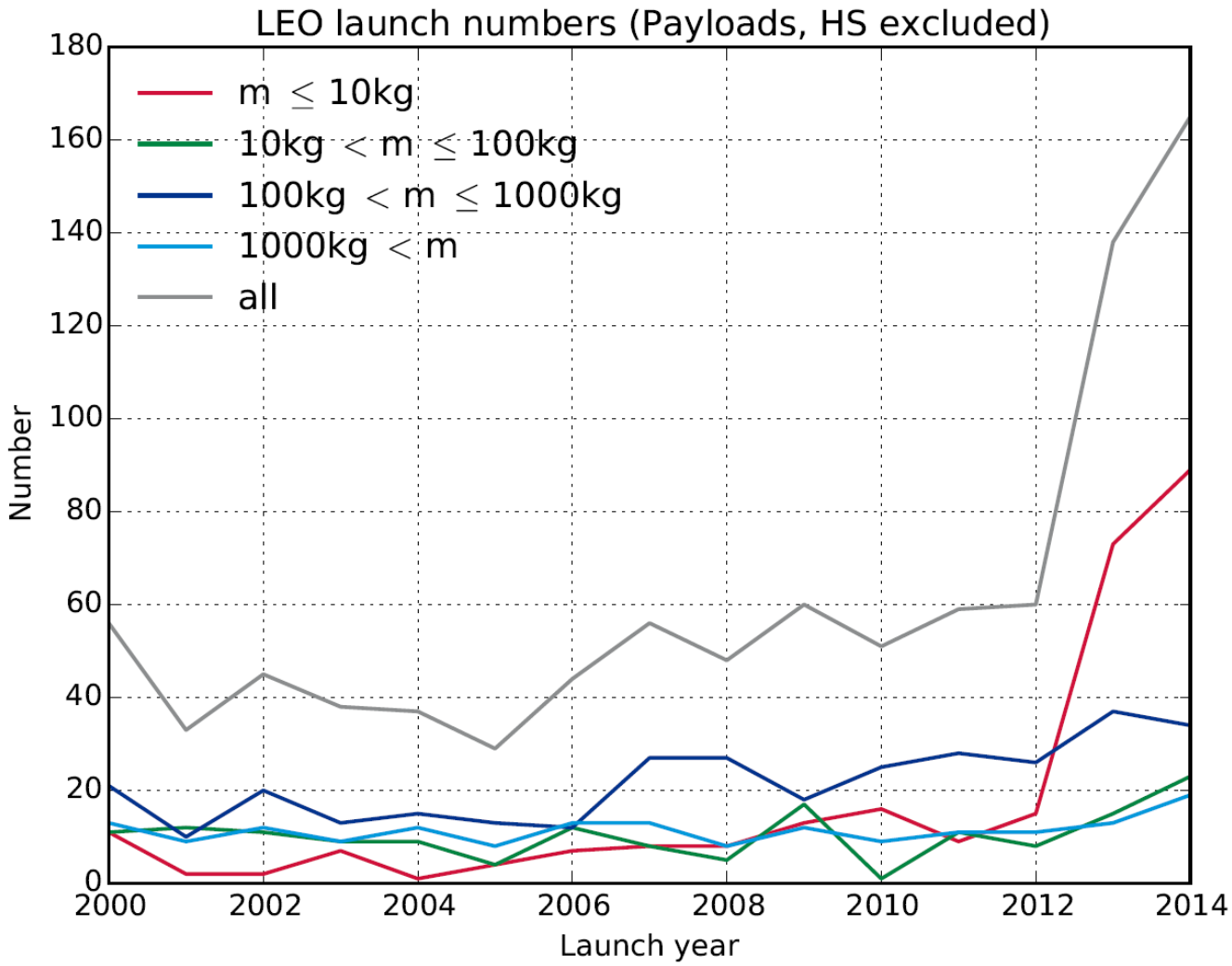


Orbital Regions of Interest (2/2)



Orbital Lifetime

Recent Changes to the Space Traffic



Future Mega-Constellations

Announced LEO telecommunication constellations with > 100 satellites:

Constellation Name	Number of satellites	Orbital altitude [km]
Samsung	4600	1400
SpaceX	4000	1100
Oneweb	650	1200
Leosat LLC	140	1800
Yalini	135	600

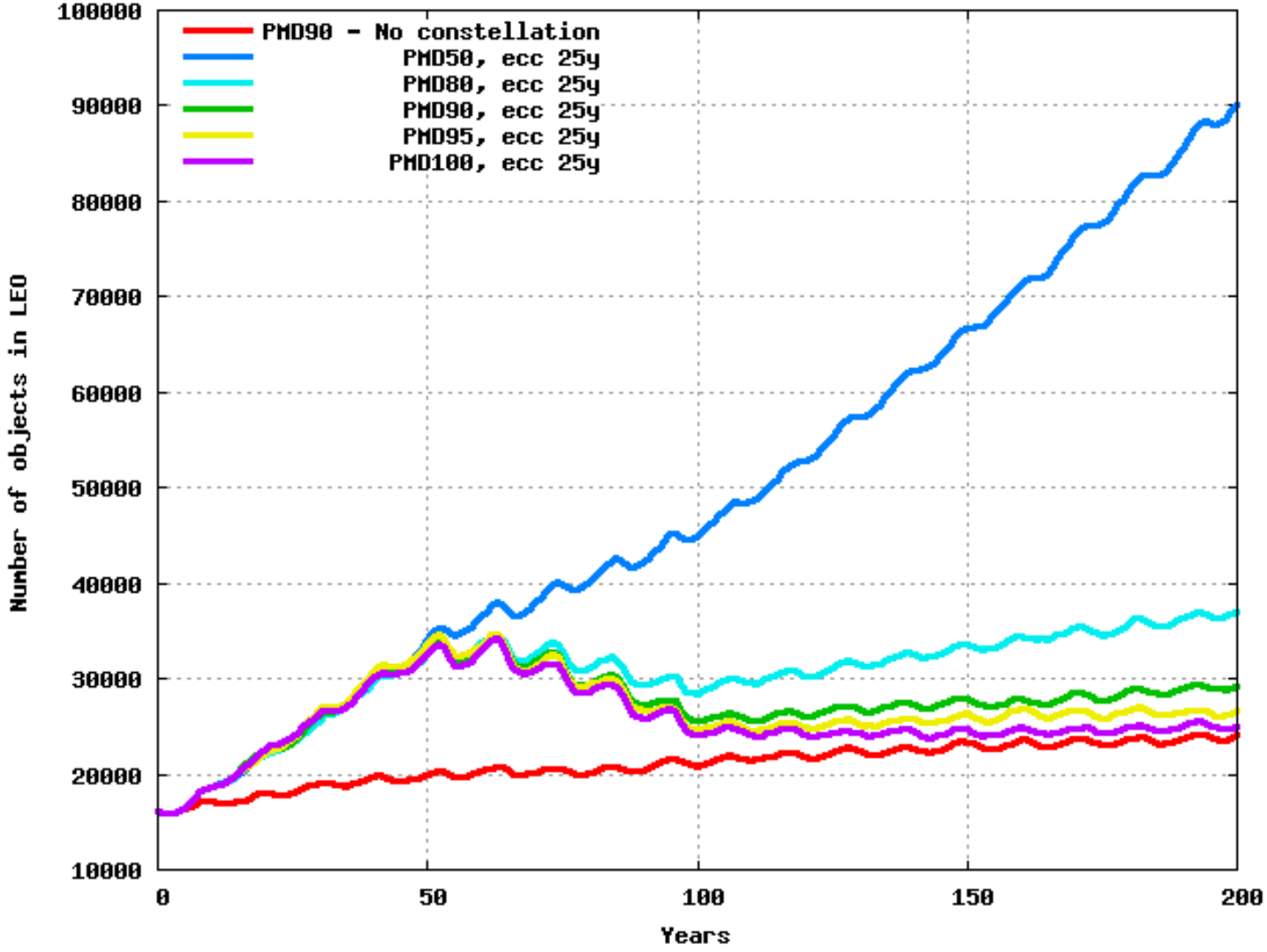
Source: Various News Articles

"Synthetic" Constellation Study Case

Constellation	**1080 satellites** **1100km altitude** **20 orbital planes** **85deg inclination**
Mission	Jan 2021 to Jan 2071
Satellite	200kg mass 1m² effective cross-section 5 years of mission lifetime
Constellation build-up	2018-2010 20 launches per year 18 satellites per launch
Constellation maintenance	2021-2071 18 objects per launch 12 launches per year
Mitigation behaviour	Launcher stages perform a direct re-entry No mission-related objects are released

- Background: continuation of current traffic, excellent application of mitigation guidelines

Mega Constellations and Post Mission Disposal Rates



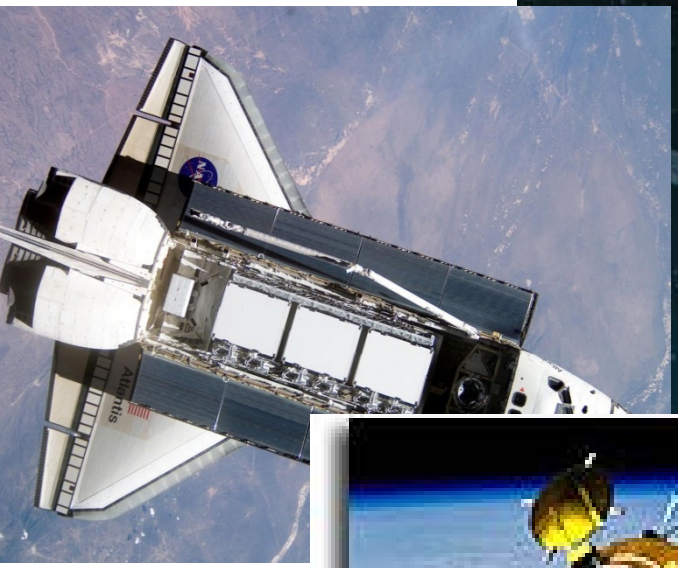
Current Disposal Efforts of LEO Constellations

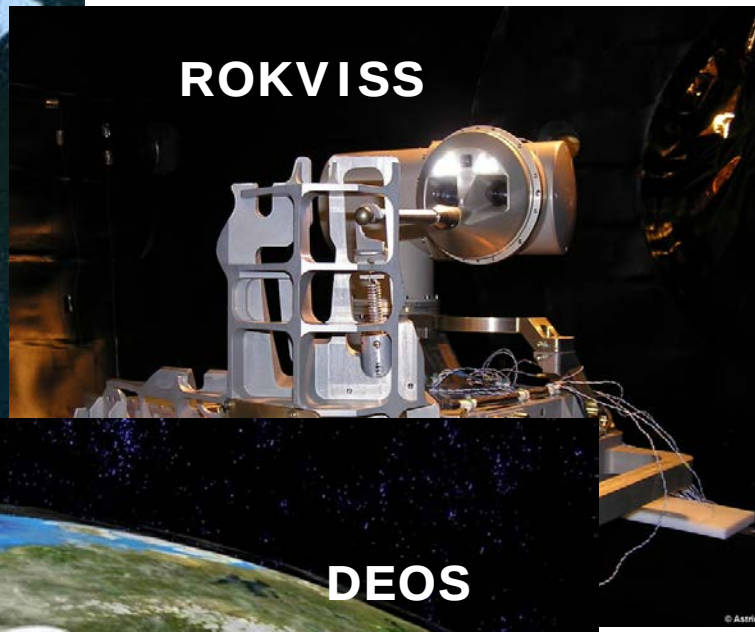
[ESA DISCOS]

Name	Orbit height [km]	Total / Active members	EoL Strategy	Compliance estimate
Orbcomm OG1	820/740	35 / 25	None observed	20%
Orbcomm OG2	710/650	6 / 6	Orbit lowering	-
Iridium	778	95 / 68	Orbit lowering	19%
Globalstar GFG	1414	60 / 14	Orbit raising	20%
Globalstar GSG	1414	24 / 24	Orbit raising	-
Gonets D	1420	11 / 1	None observed	0%
Gonets M	1502	13 / 12	None observed	0%

- State-of-the-art is at 20% (target is 90%)
- Guidelines are sufficient – Adherence is insufficient

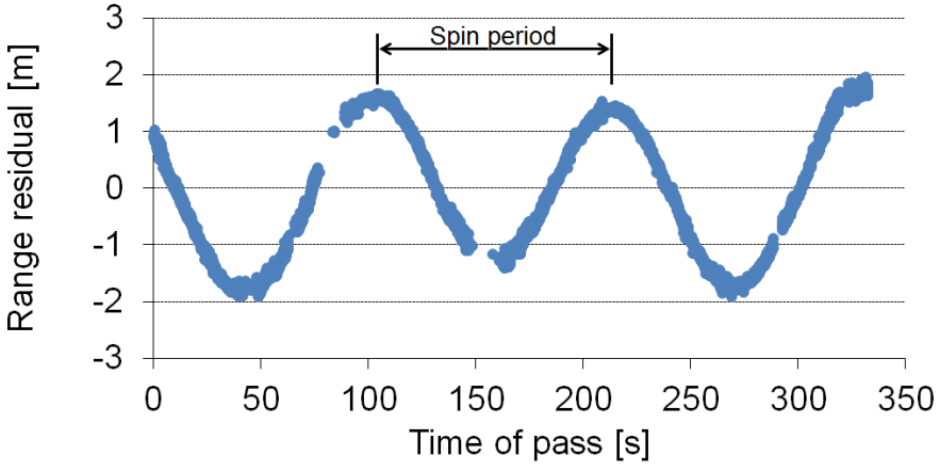
Past and current Experiments

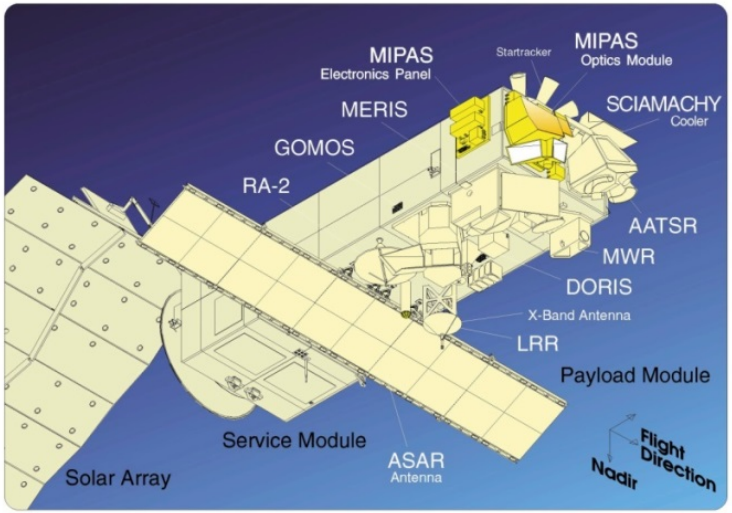




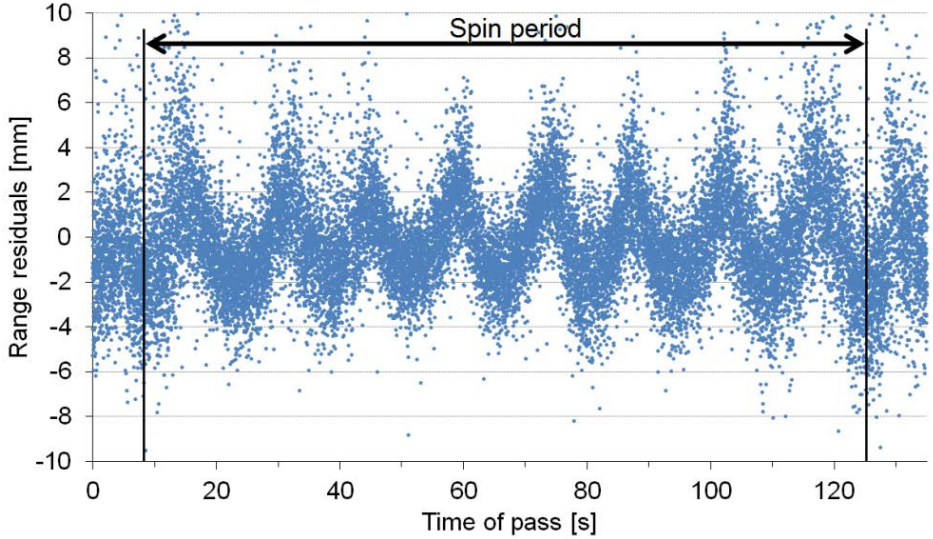
Determining the Attitude State

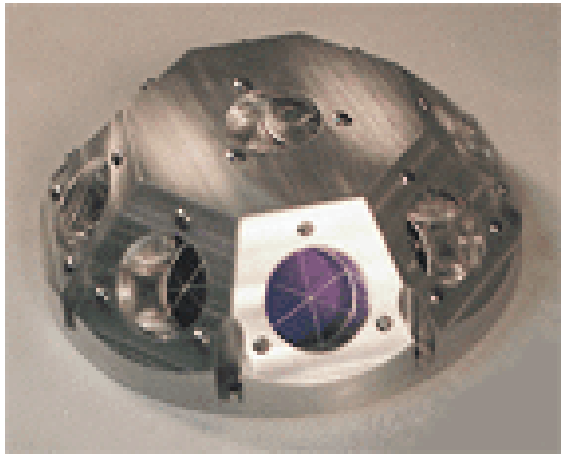
1) Analysis of meter-scale range oscillation due to 2.5 m offset between retro and spin axis of body.





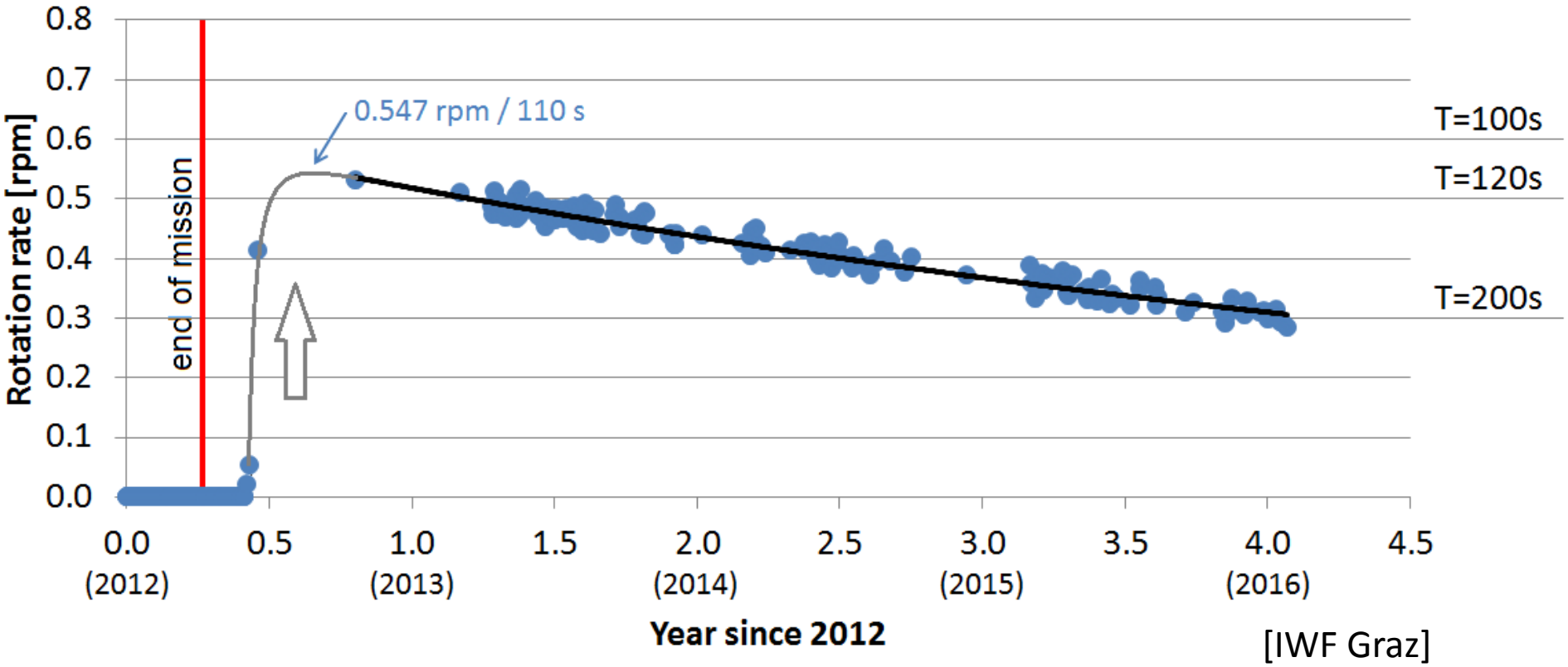
2) Analysis of the millimeter scale oscillations of the SLR range residuals; only for kHz SLR data …





retroreflector array of Envisat
consists of 8+1 corner cube reflectors

ENVISAT: Inertial Spin, measured by SLR

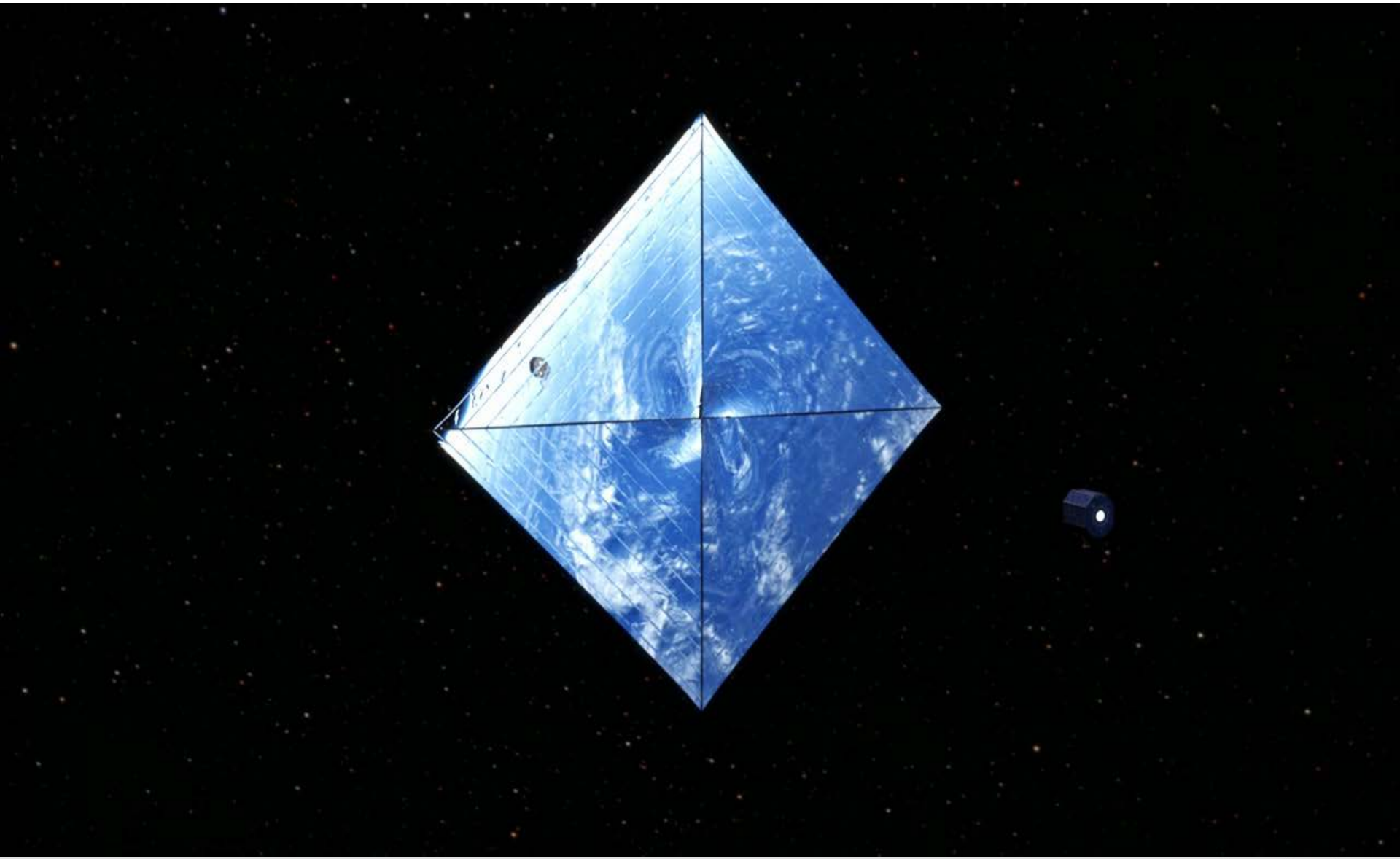


[IWF Graz]

The spin period of Envisat:

- increases by 72 ms/day
- doubles every 4 years
- will become equal to the orbital period (6000 s) in the year 2036

Capture (uncontrolled re-entry): Ion Beam Shepherding



Re-entry Risk

- Ca. 10% increase in the number of uncontrolled re-entries per year
- But targets are more heavy than average
- However: Legal concerns!!

Capture (controlled re-entry): Robotic Arm

Capture (controlled re-entry): Net