Analysing the Effect of Environment Remediation

McGill Second International Interdisciplinary Congress on Space Debris Remediation

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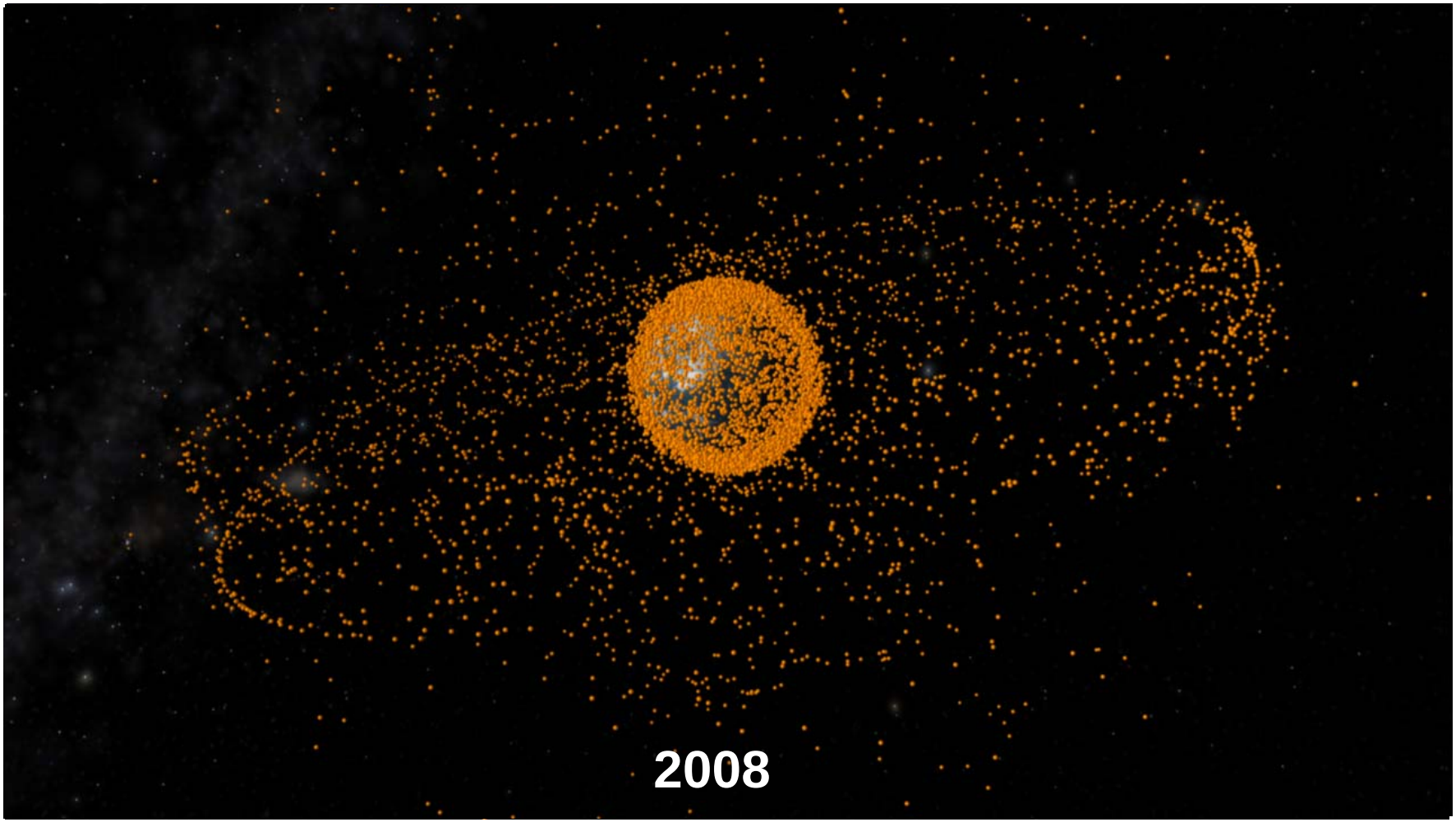
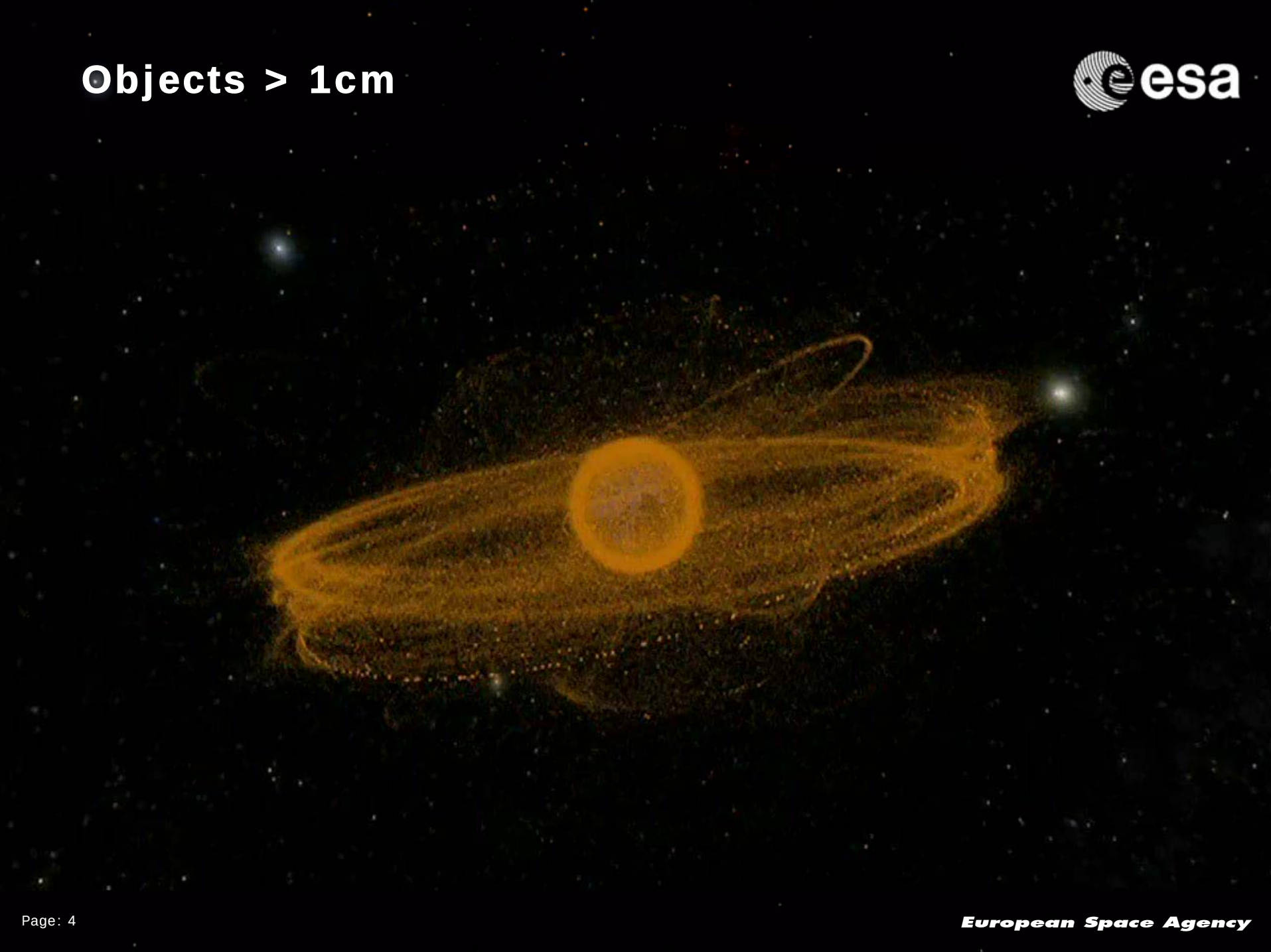
Contents

Distribution of Known Objects

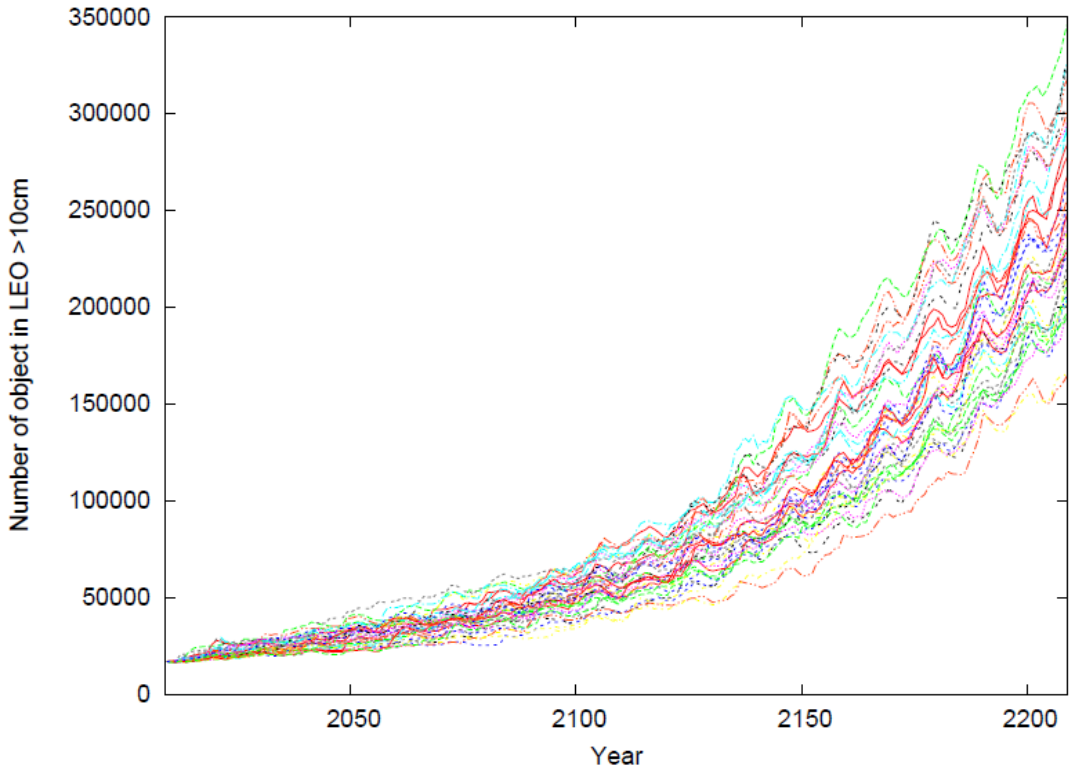


Objects > 1cm



Environment Projections

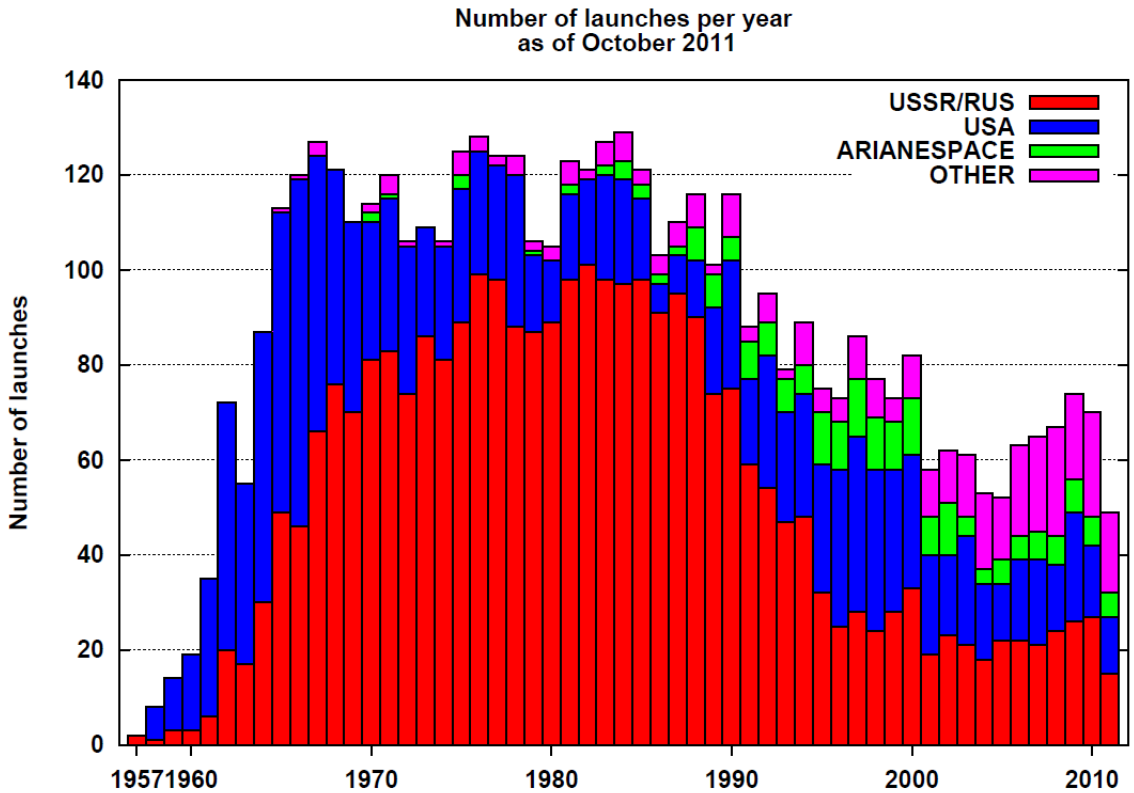
- DELTA
  - Debris Environment Long-Term Analysis
  - 3-D time dependant semi-deterministic model
  - Traffic models (launch cycle o the past 8 years)
  - Debris mitigation measures
  - Simulation of environment response to active debris removal
- 200 years forecast (2009-2209)
- Population above 10 cm
- Several Monte Carlo Runs performe



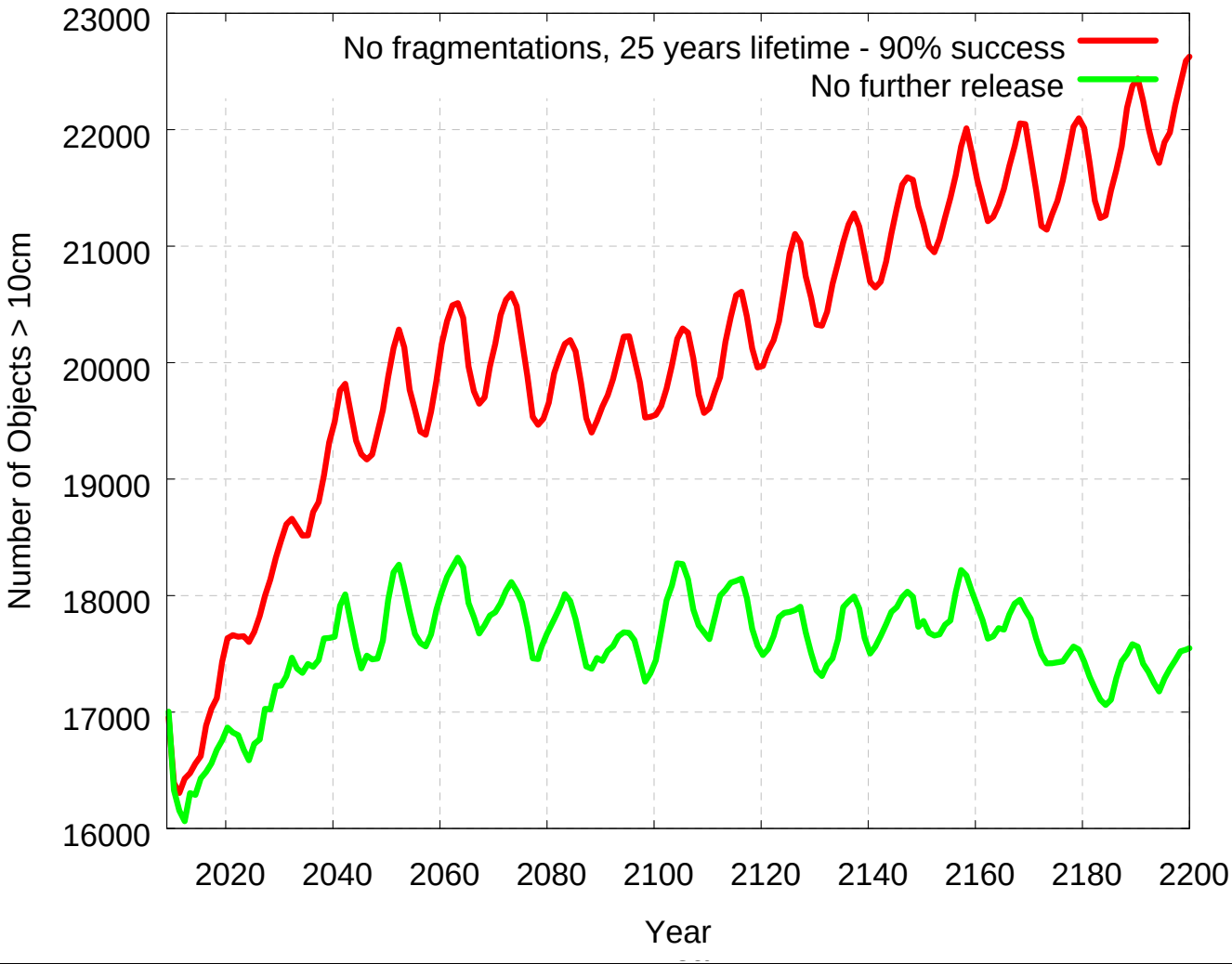
The current launch rate

- Decay of 0.15% of the “intacts” per year → 5 objects/year (no further release)
- Current launch rate → 36 launches in LEO per year (2 objects injected per launch (1 payload and 1 rocket body))

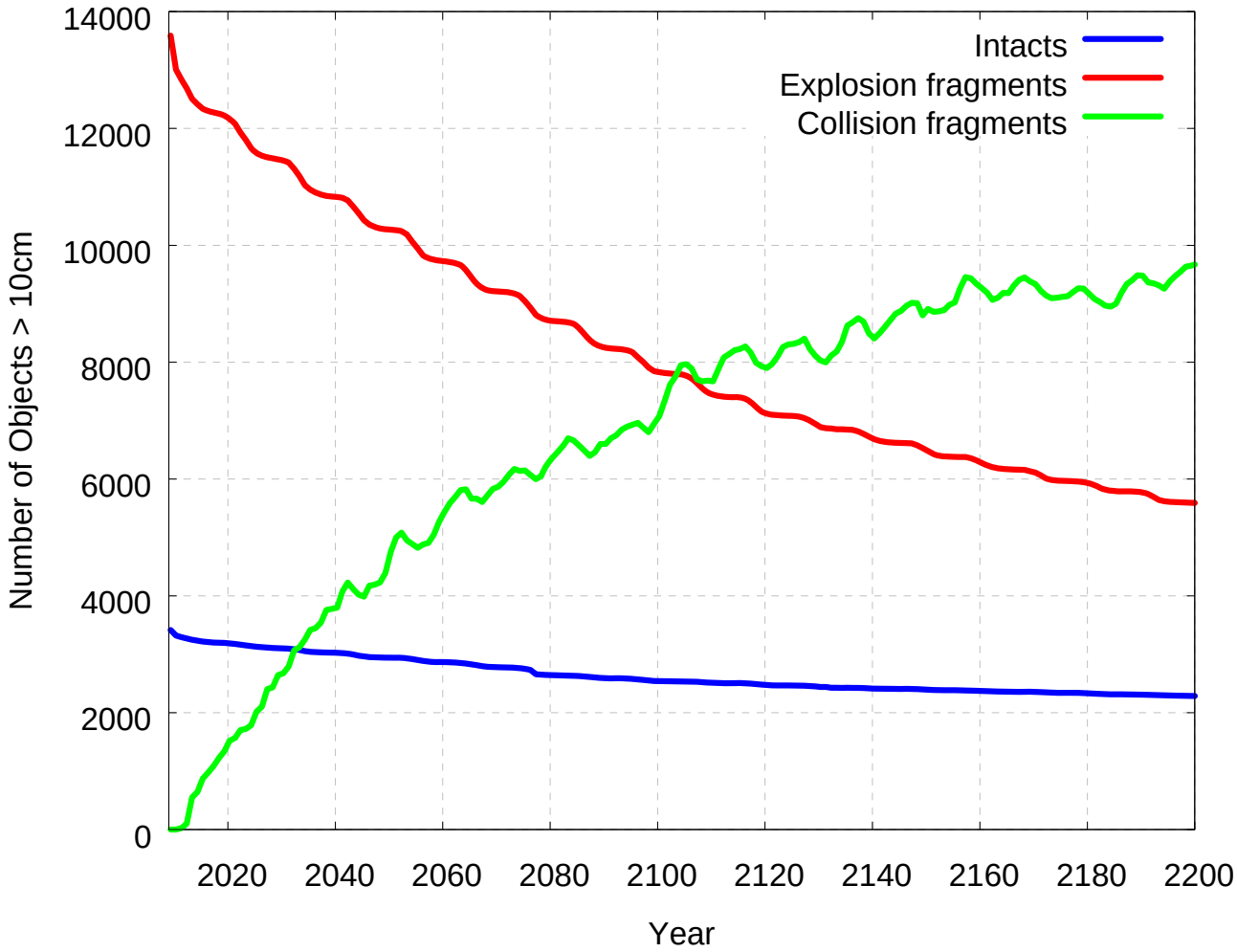
→ 67 new objects in LEO every year



DELTA results: Future evolution of the environment



Introduction : Future evolution of the environment



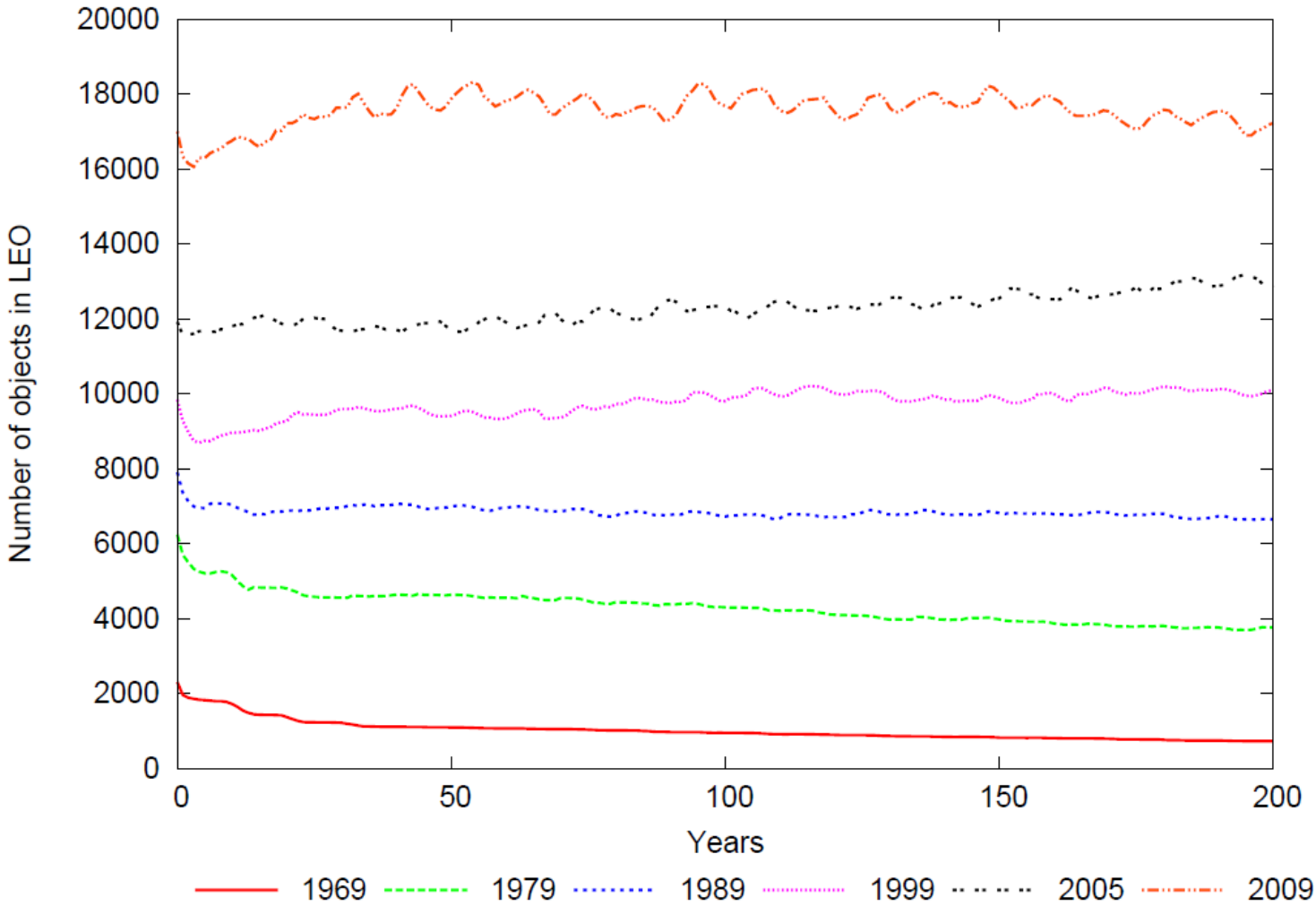
Analysis of different historical populations

No further release:

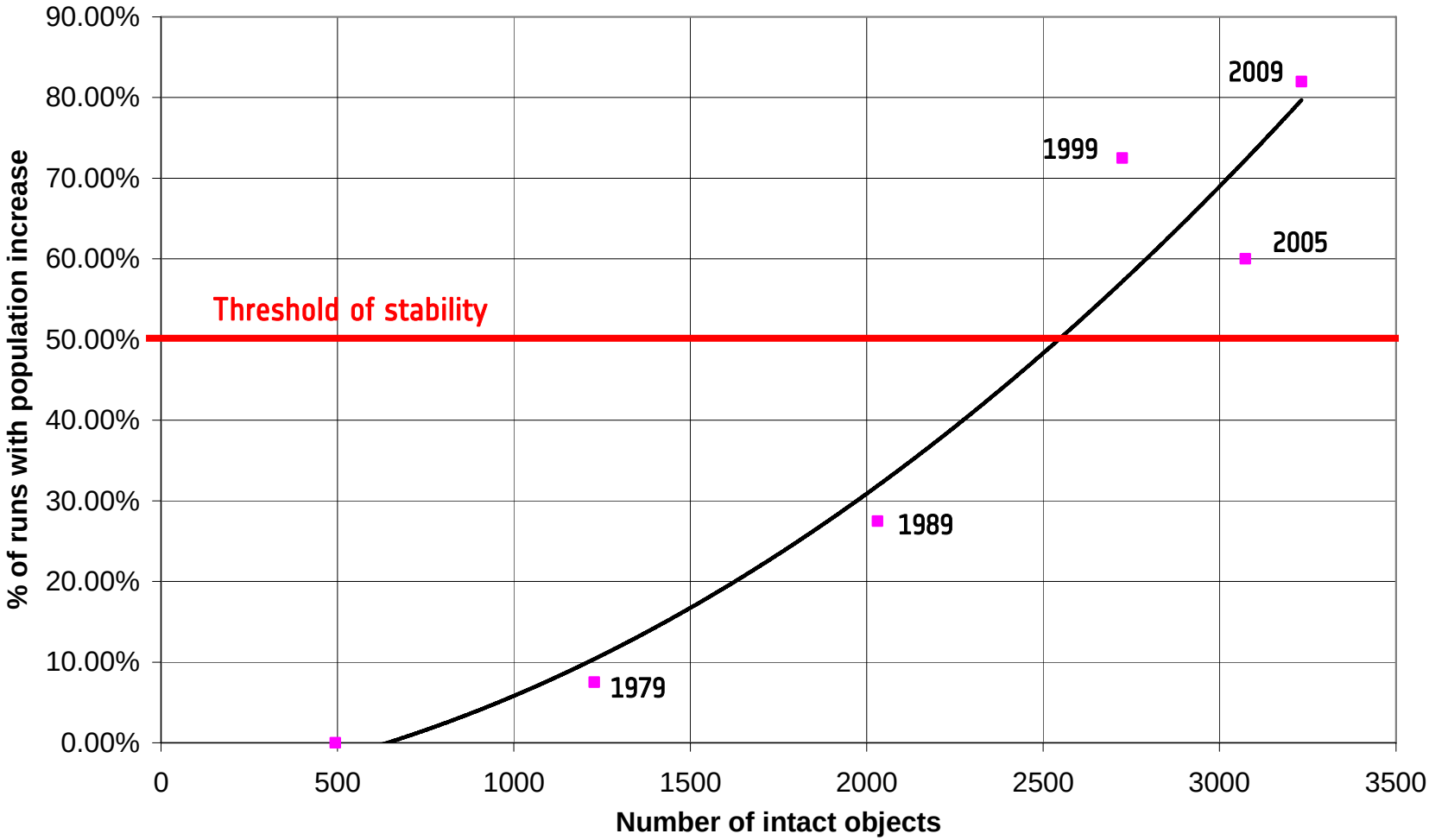
- No launches
- No explosions

Historic initial populations at different epochs from MASTER

200 years propagation



Stability of historical populations



Limiting the number of intact objects

3 Options:

- ***Lifetime Limitation:*** 25 years lifetime limitation → constant number of objects added to intacts → (launches/year x object lifetime)

Lifetime (years)	Satellites (8 years of mission)	Rocket bodies	Total
5	468	180	648
15	828	540	1368
25	1188	900	2088

- ***Launch Rate Reduction:*** Limit launches into LEO (currently: 72 intacts per year) →No legal means
- ***Active Debris Removal:*** Removal of intact objects (defunct satellites and rocket bodies) →Only acceptable if lifetime limitation requirement is fulfilled

Combination of Methods

There are different ways to come back to a population of not more than 2500 intacts:

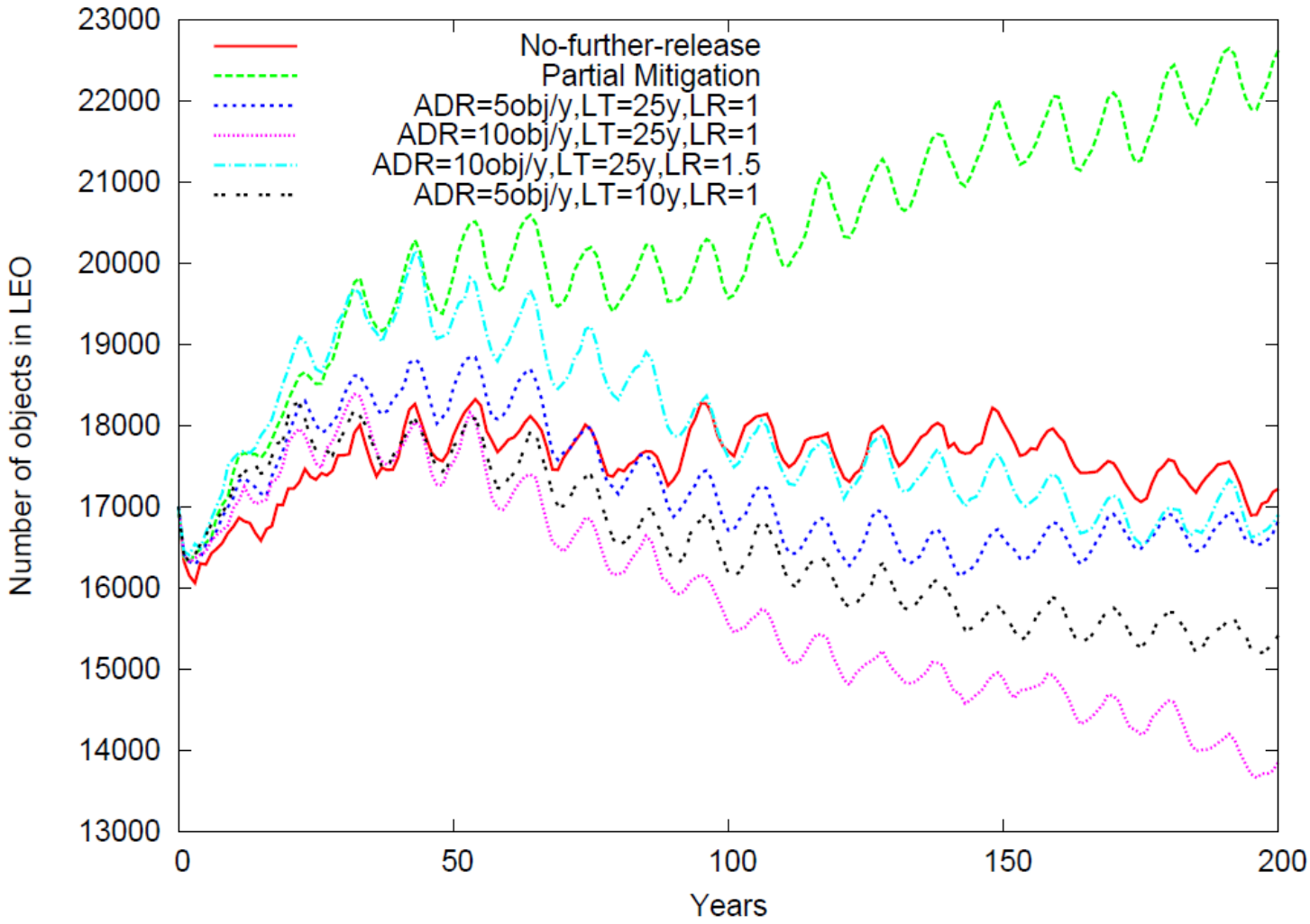
	Success of lifetime limitation	Lifetime limitation (years)	Number of launches in LEO	Years to reach threshold	ADR need (objects/year)
Reference case:	100%	25	36	100	19.4
Lifetime compliance:	90%	25	36	100	20.5
Lifetime reduction:	100%	10	36	100	11.3
Launch rate:	100%	25	18	100	11.2
	100%	25	54	100	27.6
By when is stability to be achieved?	100%	25	36	200	7.2
Realistic Case:	90%	25	36	200	9.1

Simulation results of selected cases

Removal order: by object mass

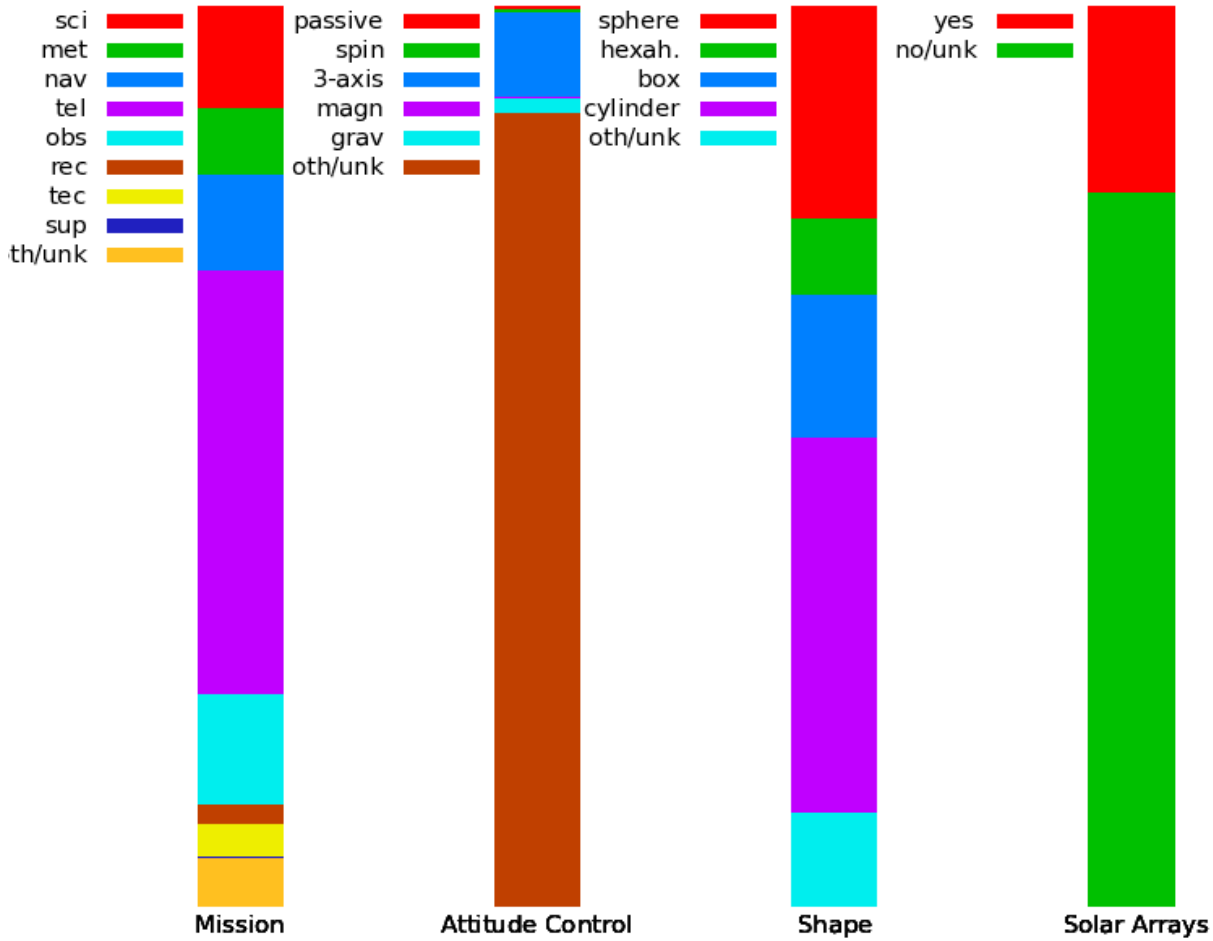
LT: Lifetime limitation to 10 or 25 years with 90% success of de-orbiting and re-orbiting measures

LR: Launch Rate scaled by 1 or 1.5 of the current rate



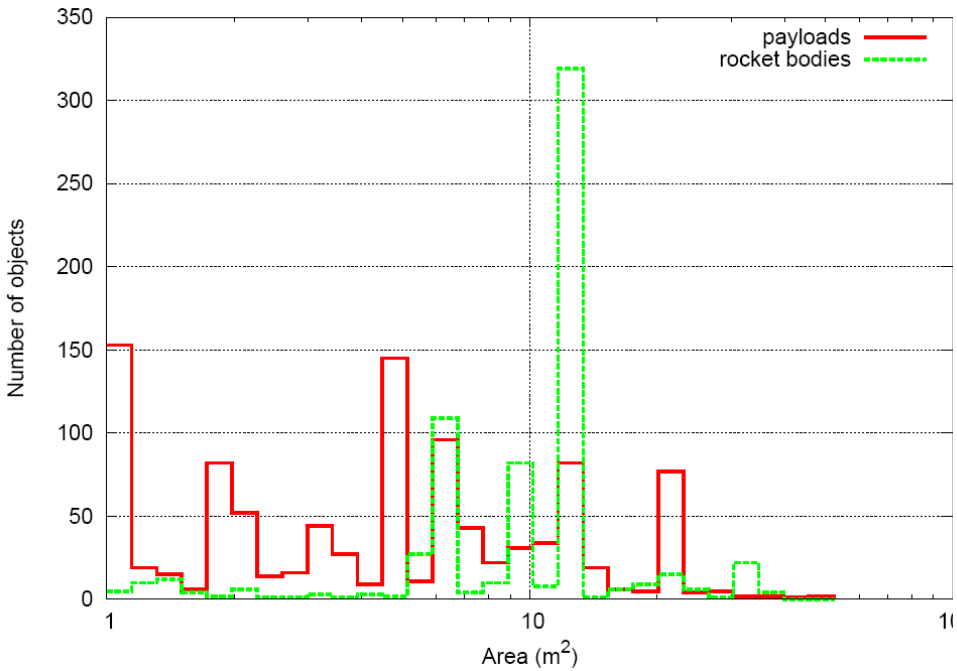
Selection of removal targets

17,000 objects > 10 cm intersect LEO (May 2009), out of which 3,500 “intacts”

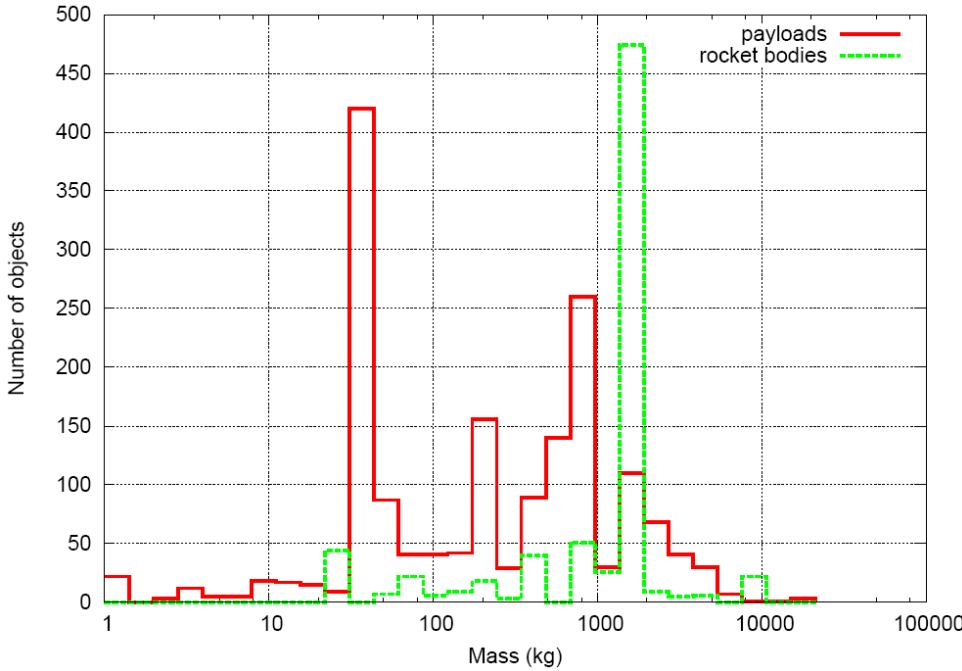


Object characteristics

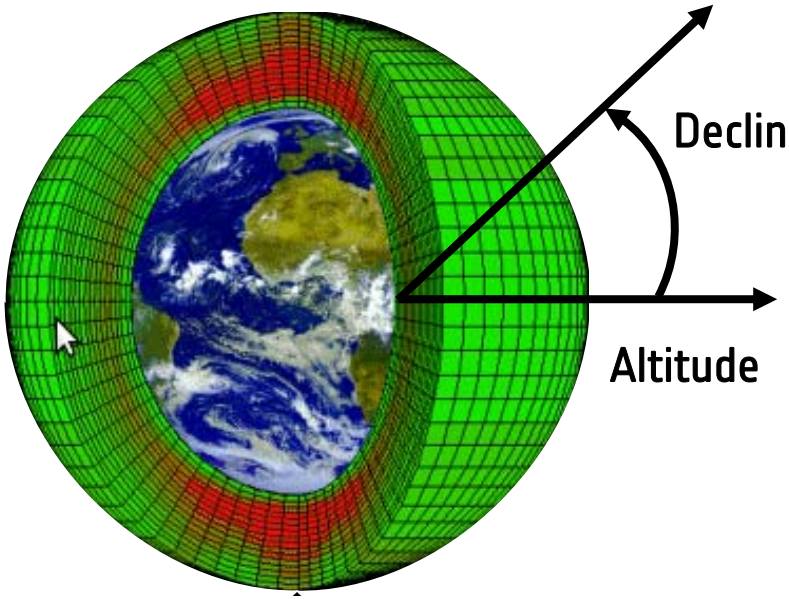
Larger area → higher collision probability

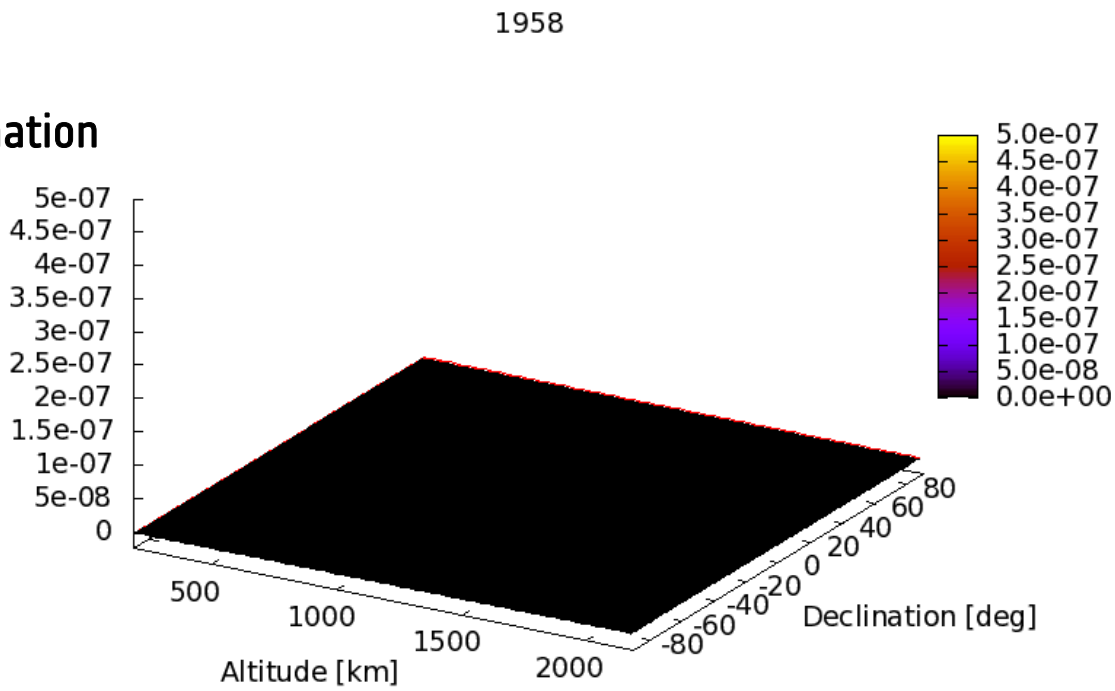


Larger mass → higher fragment number

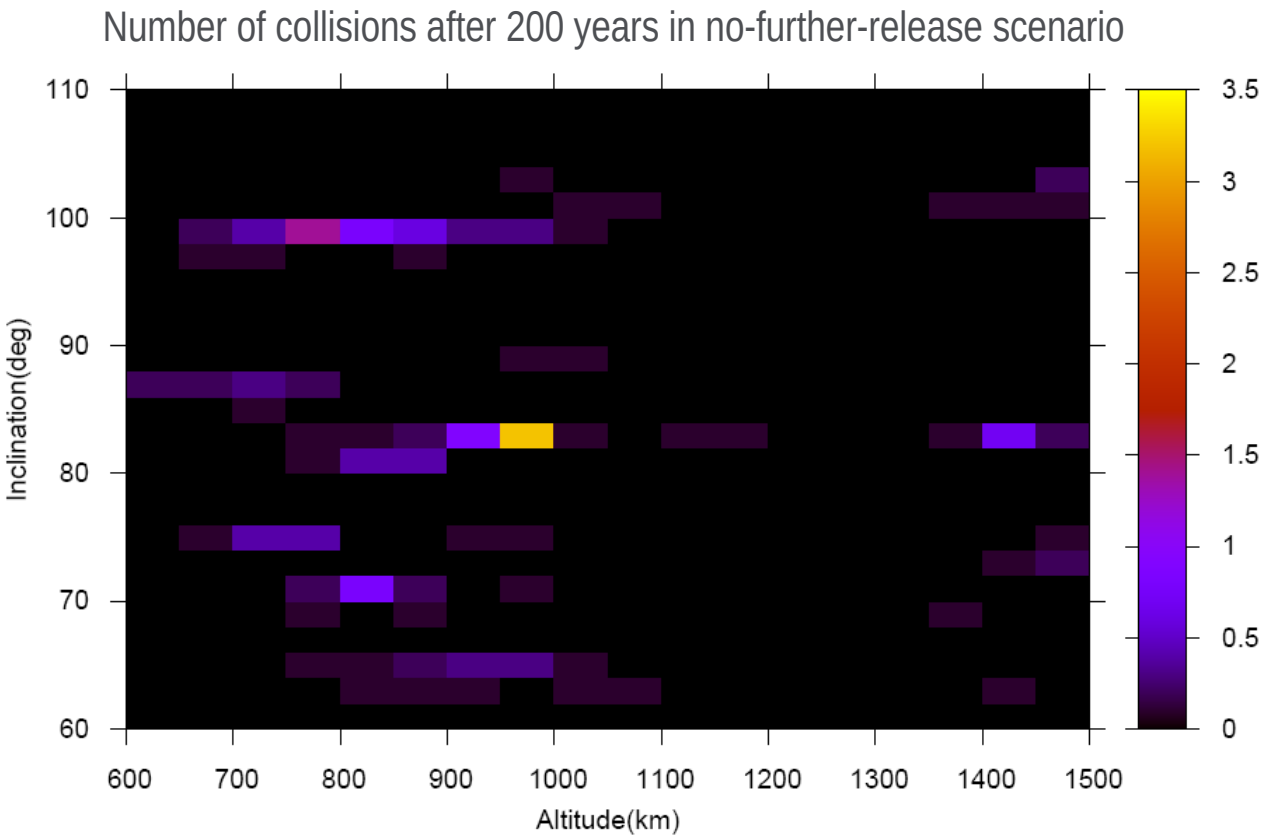


Spatial density hot spots





Orbital regions of interest



	(1000km,82deg)	(800km,99deg)	(850km,71deg)
altitude(km)	900-1100	700-900	750-950
inclination(deg)	81-83	98-100	70-72
RAAN(deg)	90-110	90-110	90-110

Effectiveness of removal strategies

- No-further-release scenario (starting in 2006) for 200 years

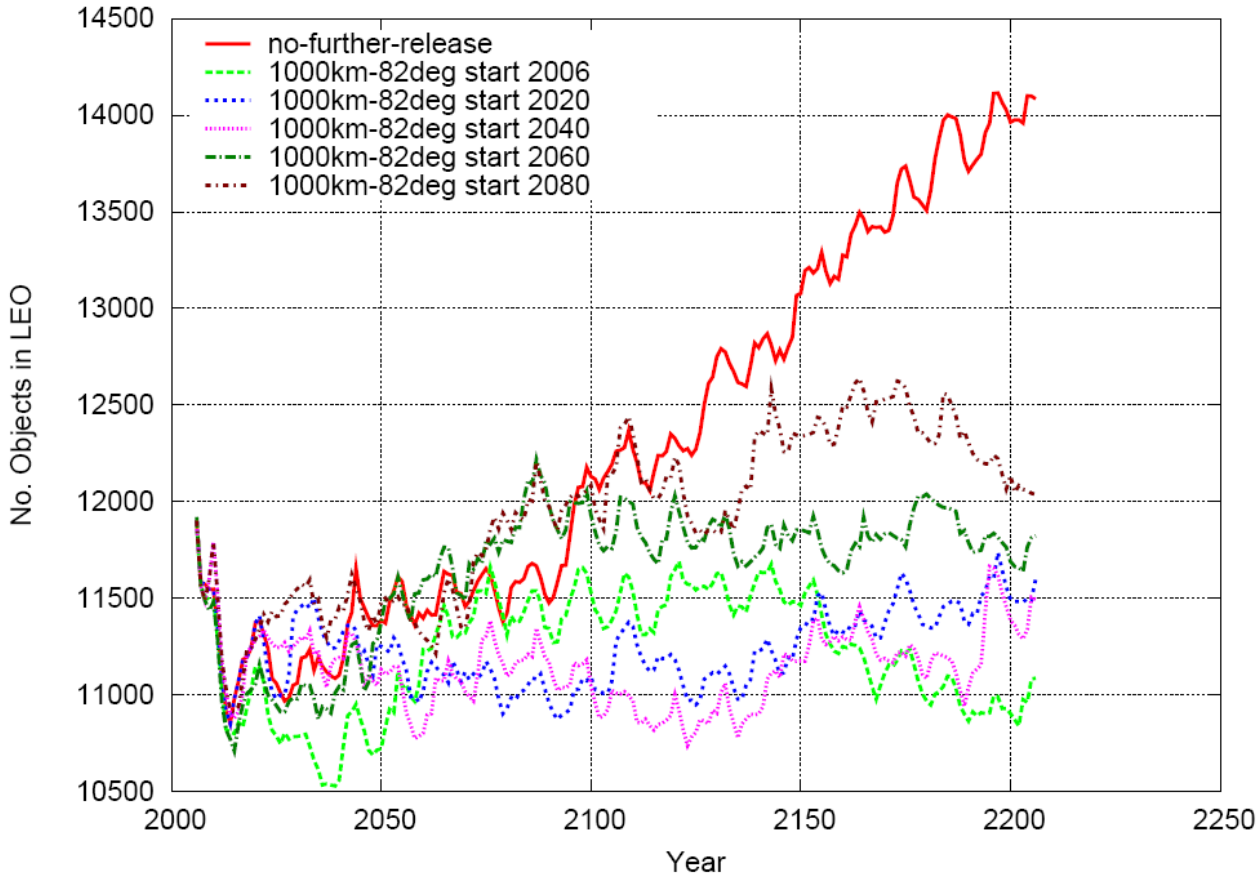
	Removal by mass	Removal by area	Removal in (1000km, 82°)	Removal in (800km, 99°)	Removal in (850km, 71°)
# objects available (removed)	1000	1000	288	142	45
# objects reduced per object removed	5.3	5.3	7.8	9.1	36.3
# collisions reduced per object removed	0.008	0.008	0.018	0.023	0.024
# population growth %	-25.8	-26.1	-0.64	7.25	4.43

Mass and area are coupled and equally important

Large masses, higher altitude

Impact of delays in the start of the activity

- No-further-release scenario, 290 objects in 1000km-82° in 58 years, Removal order by mass
  - Start in 2006, 2020, 2040, 2060 and 2080 with 5 objects removed per year



Conclusions

- ADR can be more efficient then launch rate and lifetime reduction, because the targets can be selected (optimised)
- It is important to understand in which timeframe the environment shall be stabilised
- Ideally, only one type of removal vehicle is used (requires targets to have similar characteristics)
- On average, 50 objects need to be removed to prevent one collision
- This can be optimised by selecting density hot-spots (in high altitudes)
- Criteria for removal should be (a combination of):
  - Collision probability [area, object density]
  - Altitude of the density hot spot [lifetime of fragments]
  - Mass of the object
- Delays in starting ADR activities make ADR less effective