Achieving Successful End-Of-Life Disposal in LEO

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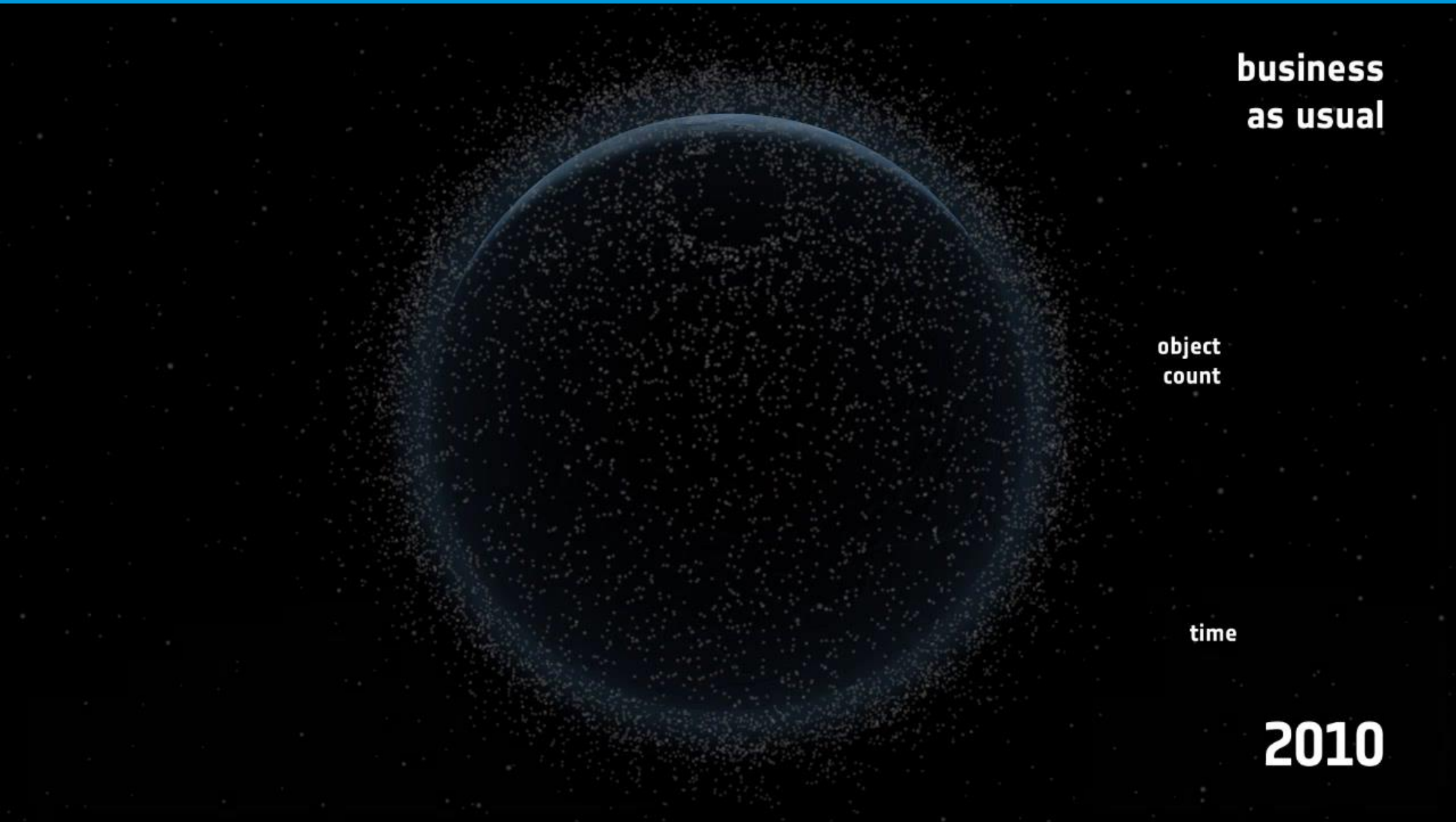
Business As Usual

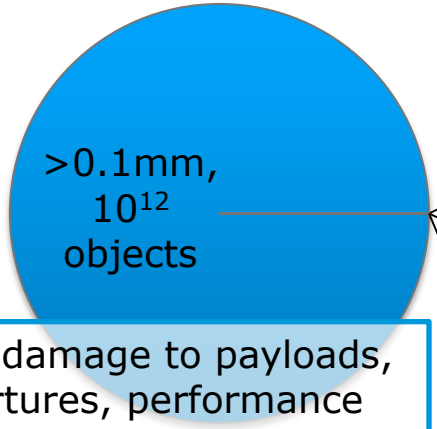


Space Debris – Sizes and Classes

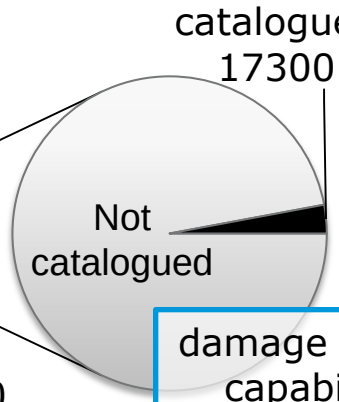
sub-orbital

orbital

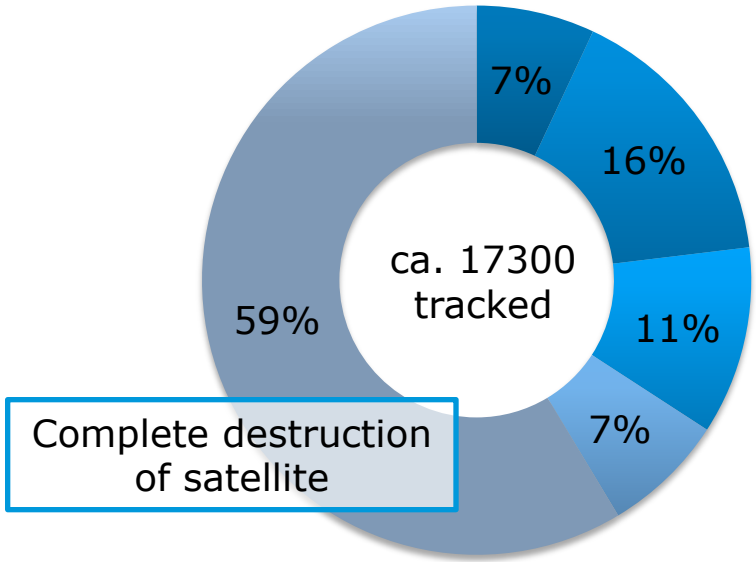
sub-orbital



small damage to payloads, apertures, performance degradation



damage to structure, loss of capabilities or payloads



Complete destruction of satellite

- Operational satellites
- Non-operational satellites
- Rocket bodies, upper stages
- Mission-related objects
- Fragments

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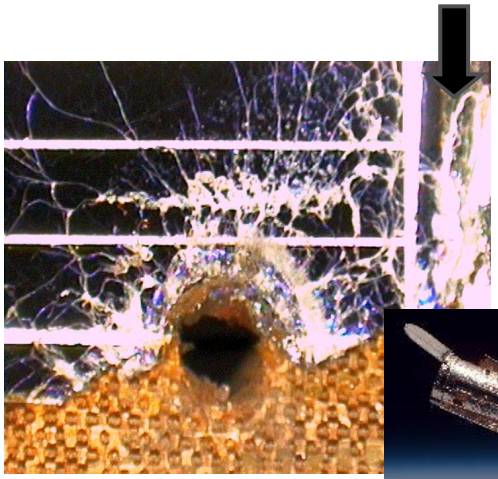
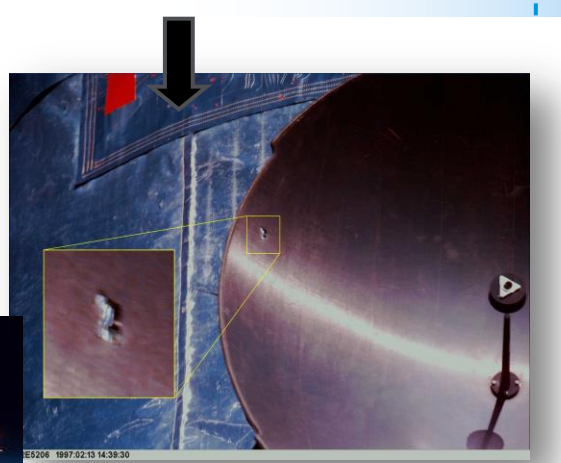
Impactor Frequency

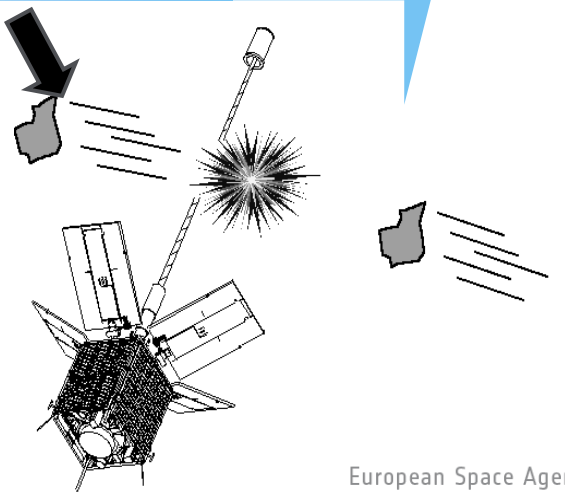
Mean time between two impacts on an cross section of $30m^2$

Altitude	>0.1mm	>1mm	>1cm	>10cm
400km	4,5 days	37 years	2,416 years	41.667 years
800km	0,1 days	2,9 years	133 years	2.483 years
GEO	17,3 days	556 years	128.205 years	1.488.095 years

Detectivity







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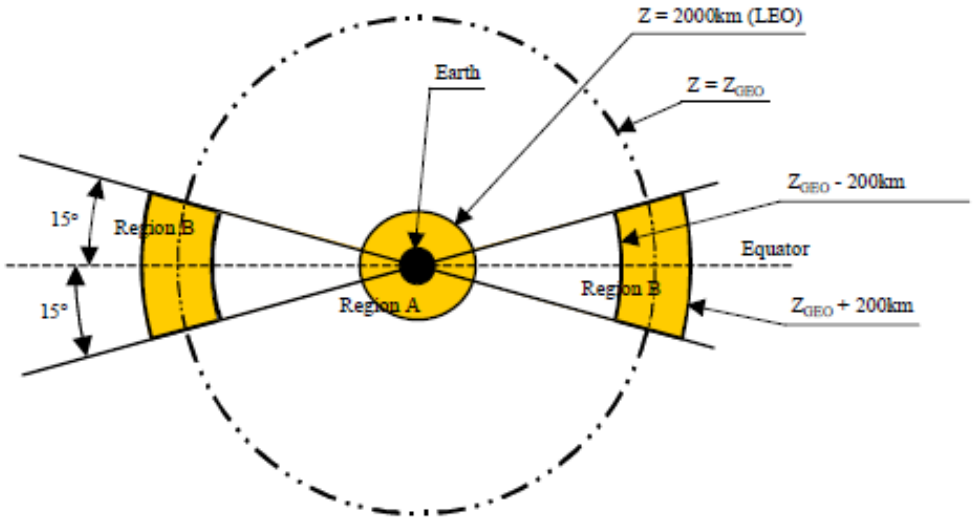
IADC Mitigation Guidelines

1. Limit debris released during normal operations
2. Minimise the potential for on-orbit break-ups
3. Prevention of on-orbit collisions
4. Post mission disposal
    a. Geosynchronous region
    b. LEO region;
       compliant if
       lifetime < 25 years

Assuming future space traffic
to remain on levels of the past



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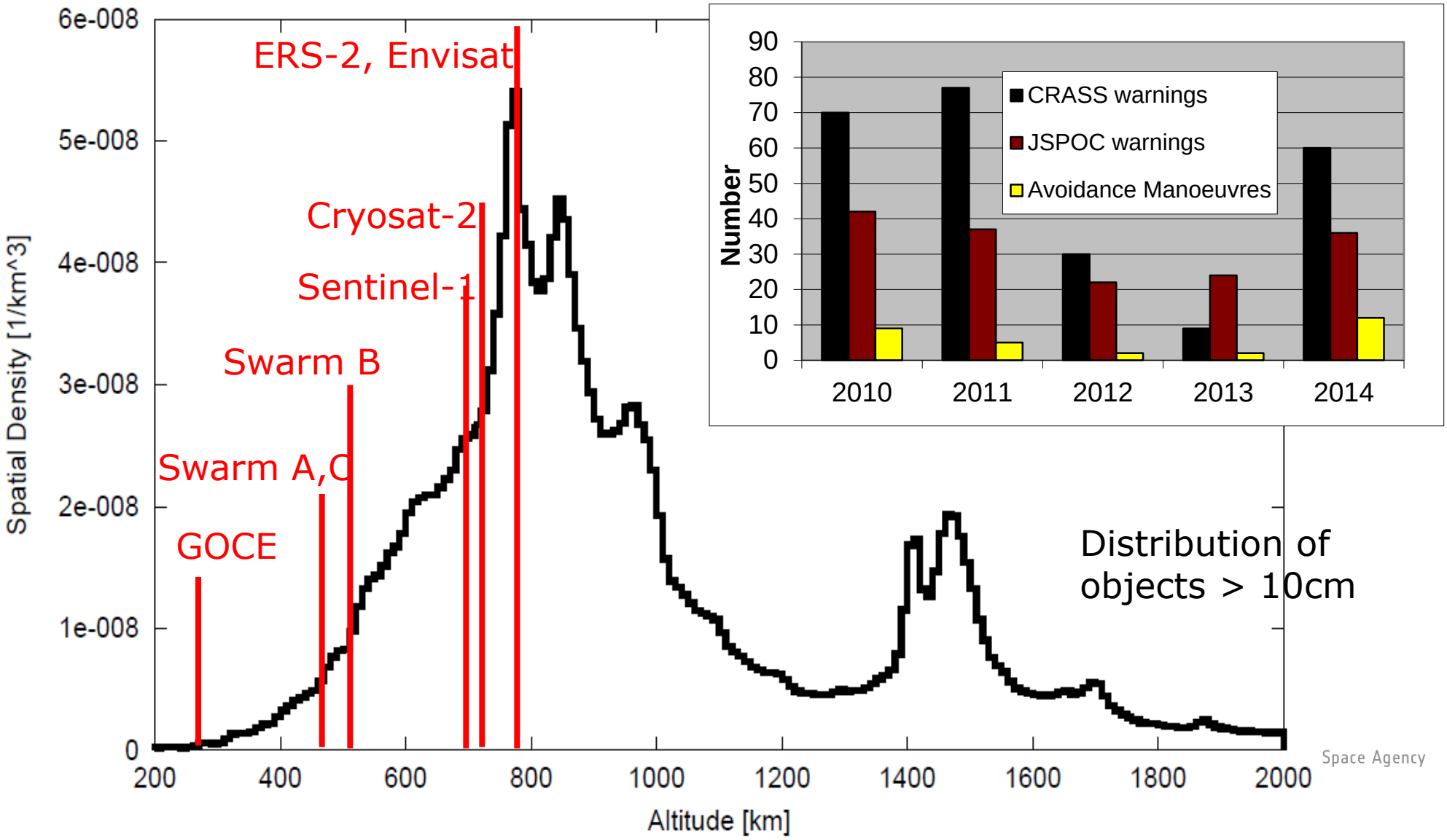
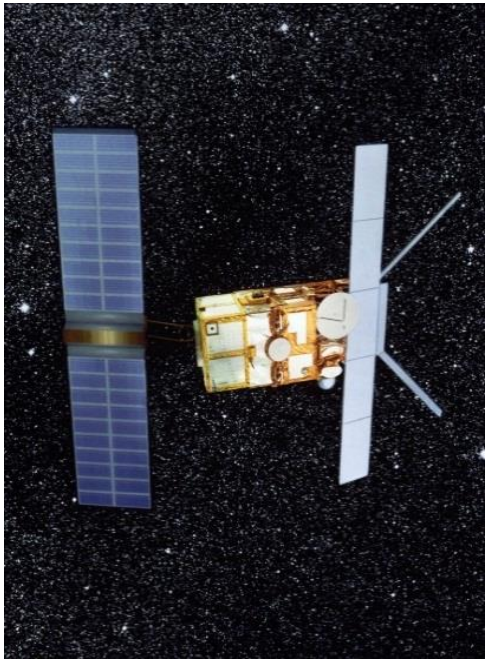
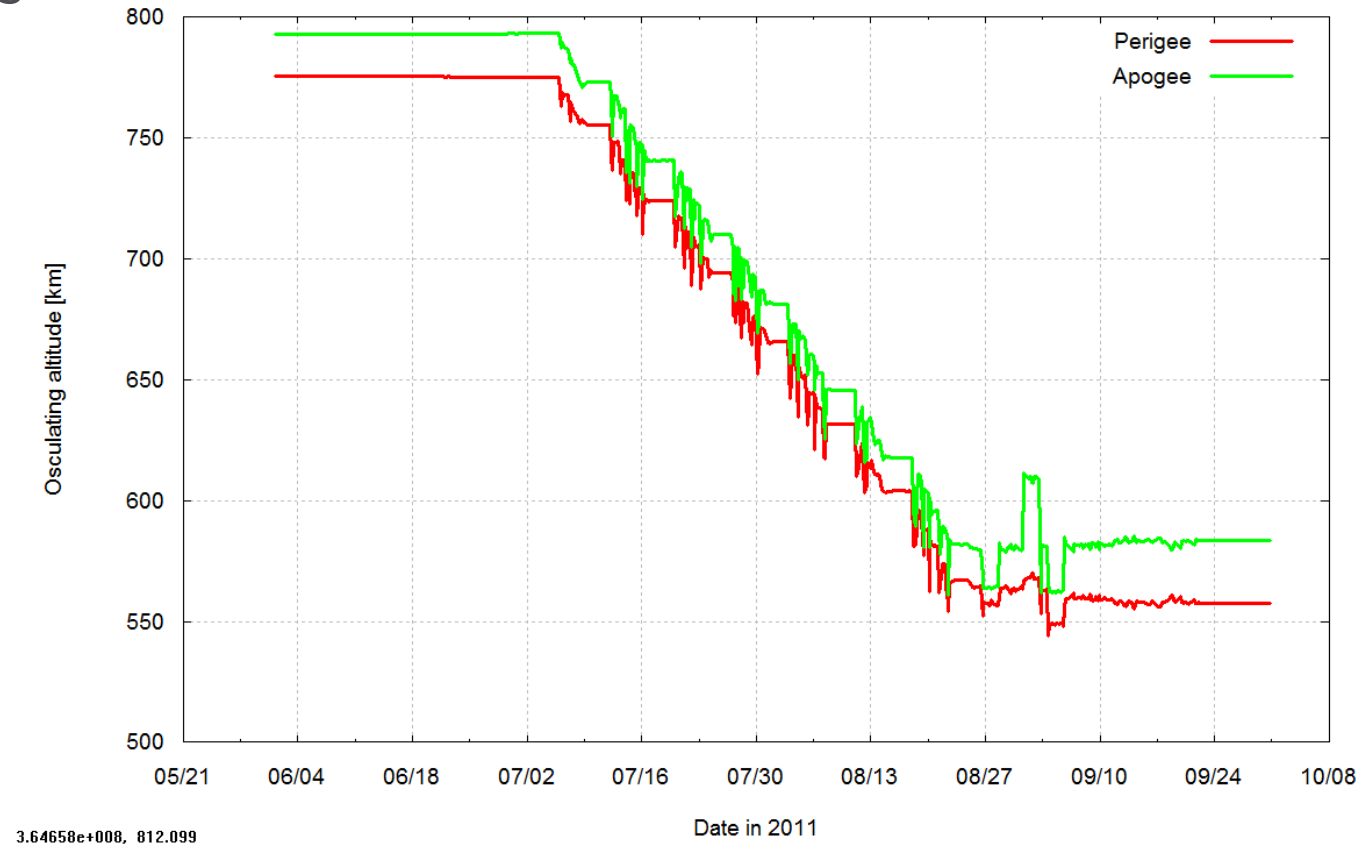
Mitigation: Collision Avoidance



Mitigation: De-orbit (ERS-2)

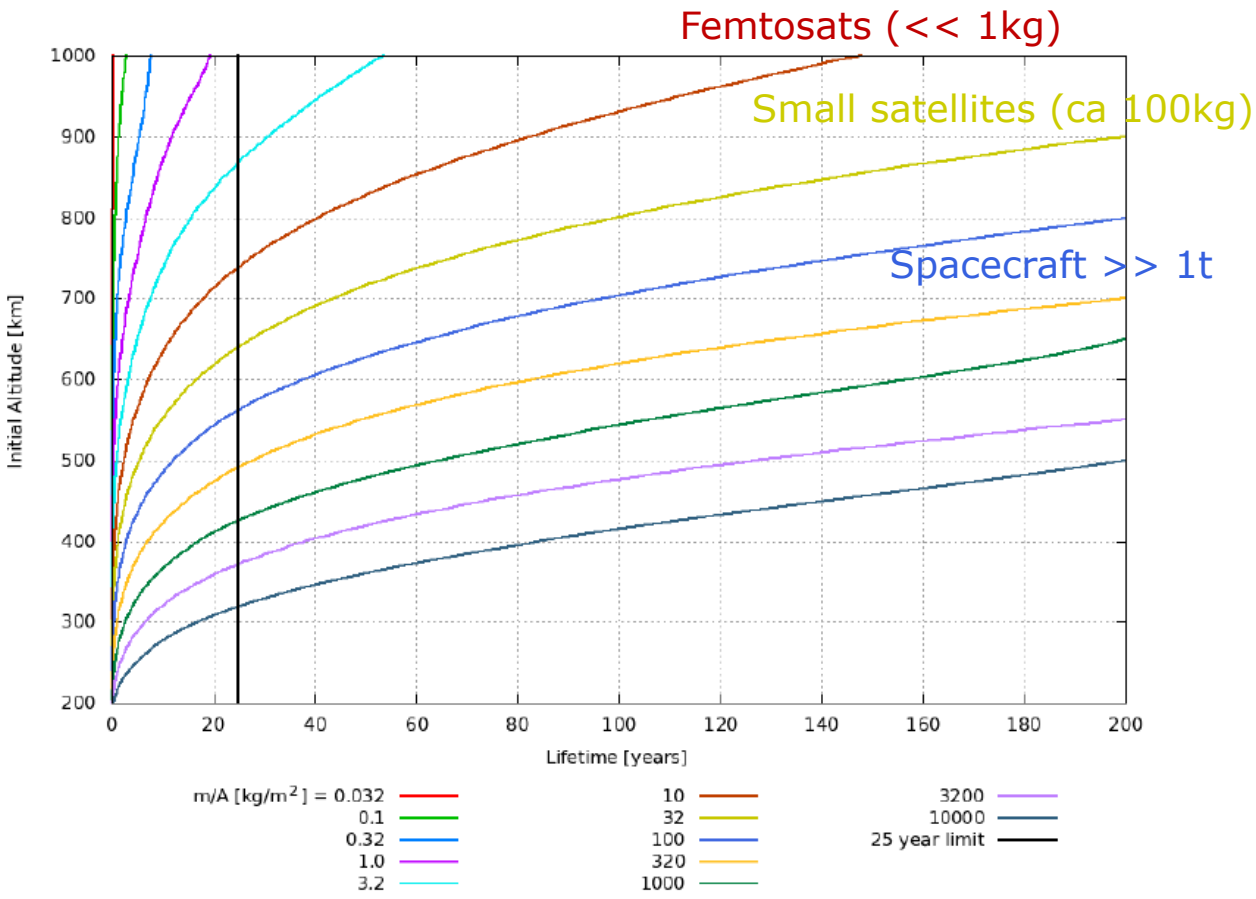
1. Estimated Lifetime before 2011: ~60 years
2. After: < 15 years



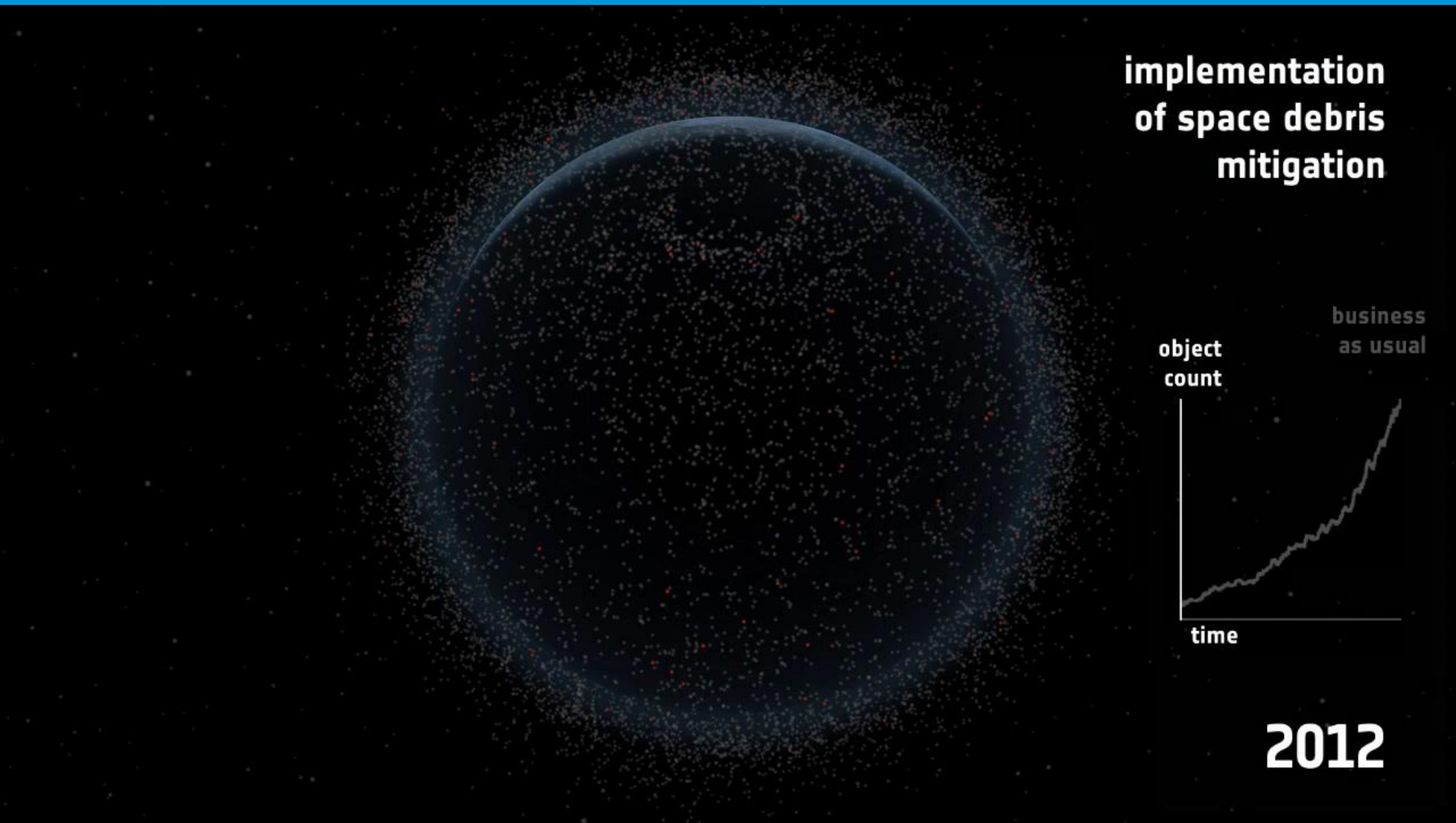


Mitigation: Orbit Selection

1. Small satellites with no Orbit Control Capabilities (OCC) need to be placed in (circular) orbits below 650km altitude
2. For satellites with very short lifetimes (weeks), an significantly lower altitude should be chosen



Guidelines in Place

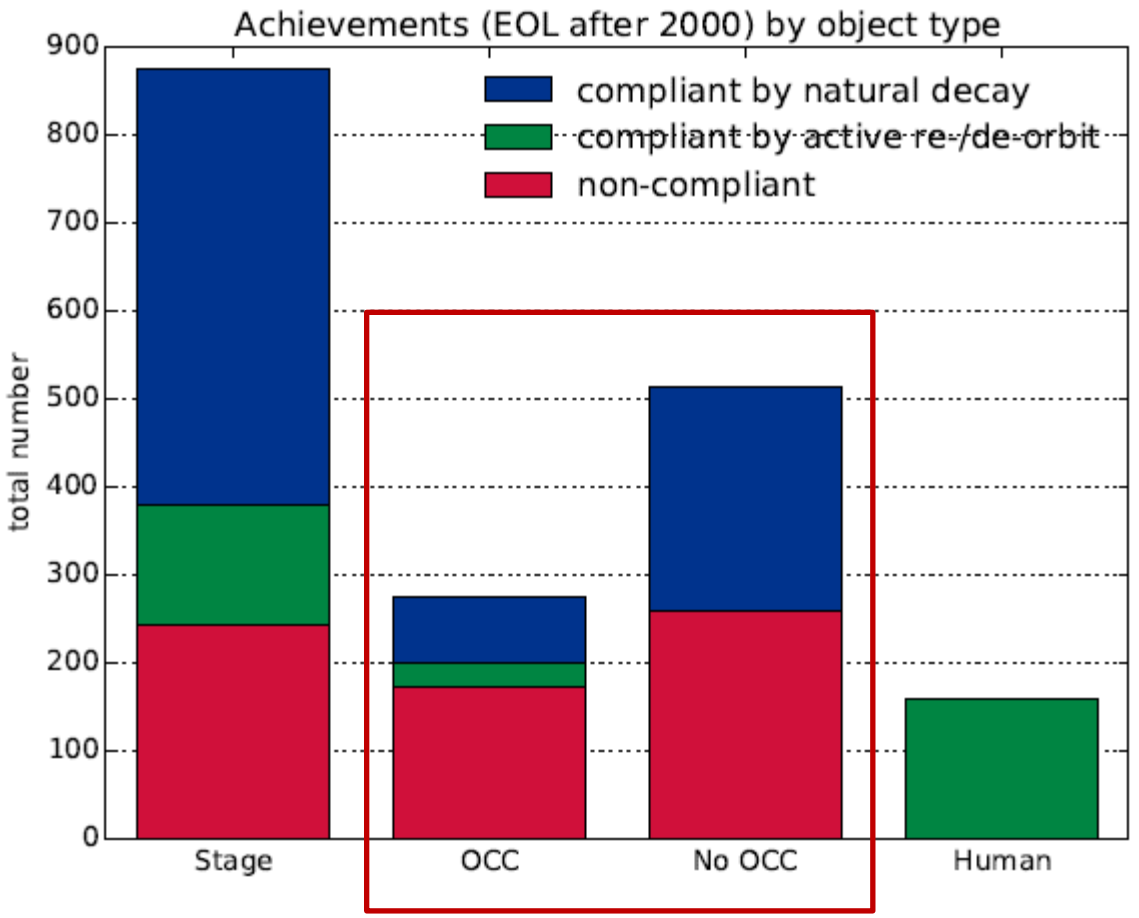


Compliance Analysis LEO

1. Space vehicles related to human spaceflight (HS) and upper-stages are separated
2. Payloads are analysed if they
    a. have perigee altitudes <2000km and launched after 1980
    b. are found to be manoeuvring in the year of analysis, but not one year later (OCC)
    c. are not found to be manoeuvring ever and elapsed a mission specific lifetime (typical lifetimes from statistics)
    d. were launched and decayed in the year of analysis

Adherence to Guidelines

1. In order to adhere to the guidelines, payloads without OCC depend on natural decay
2. However, roughly 50% of those were launched to orbits where not enough residual atmosphere is left



OCC = Orbit Control Capacity

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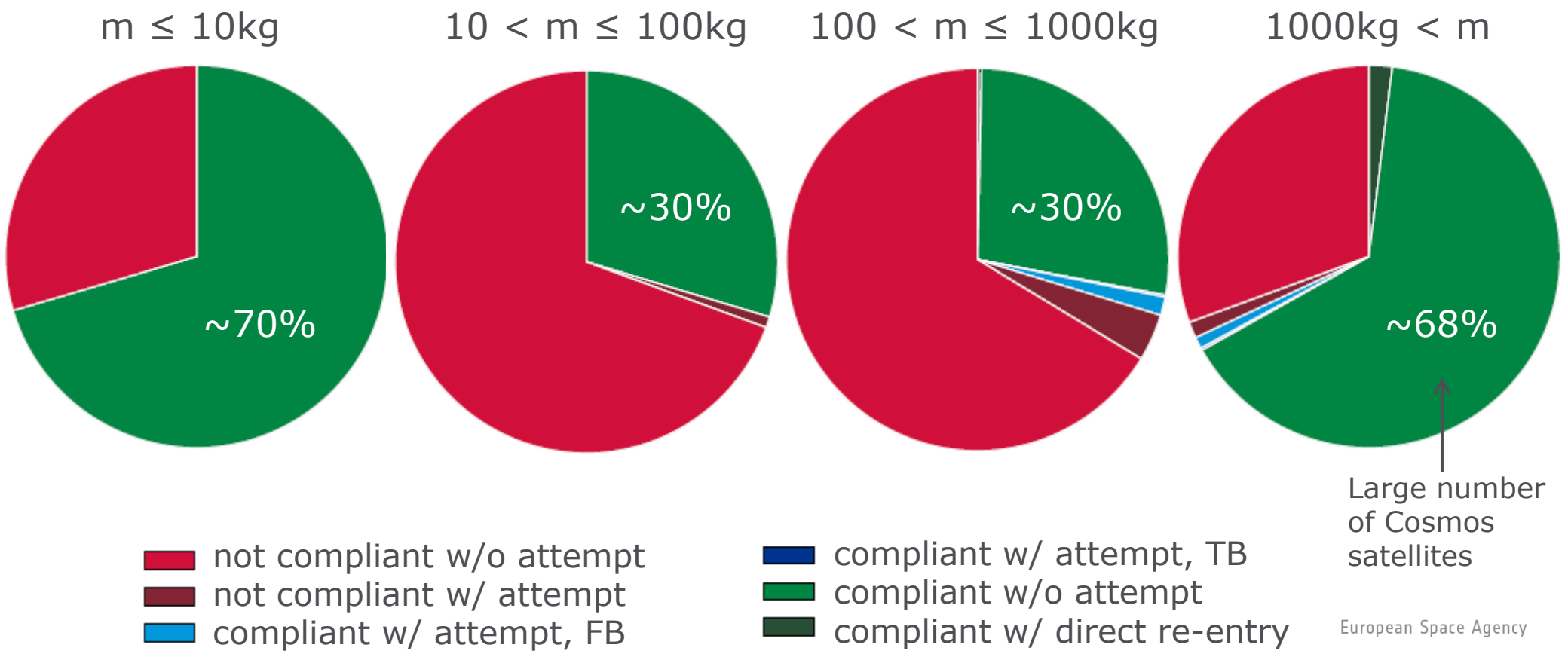
LEO Clearance

1. Compliances (payloads w/o human spaceflight, EOL ≥ 1990)



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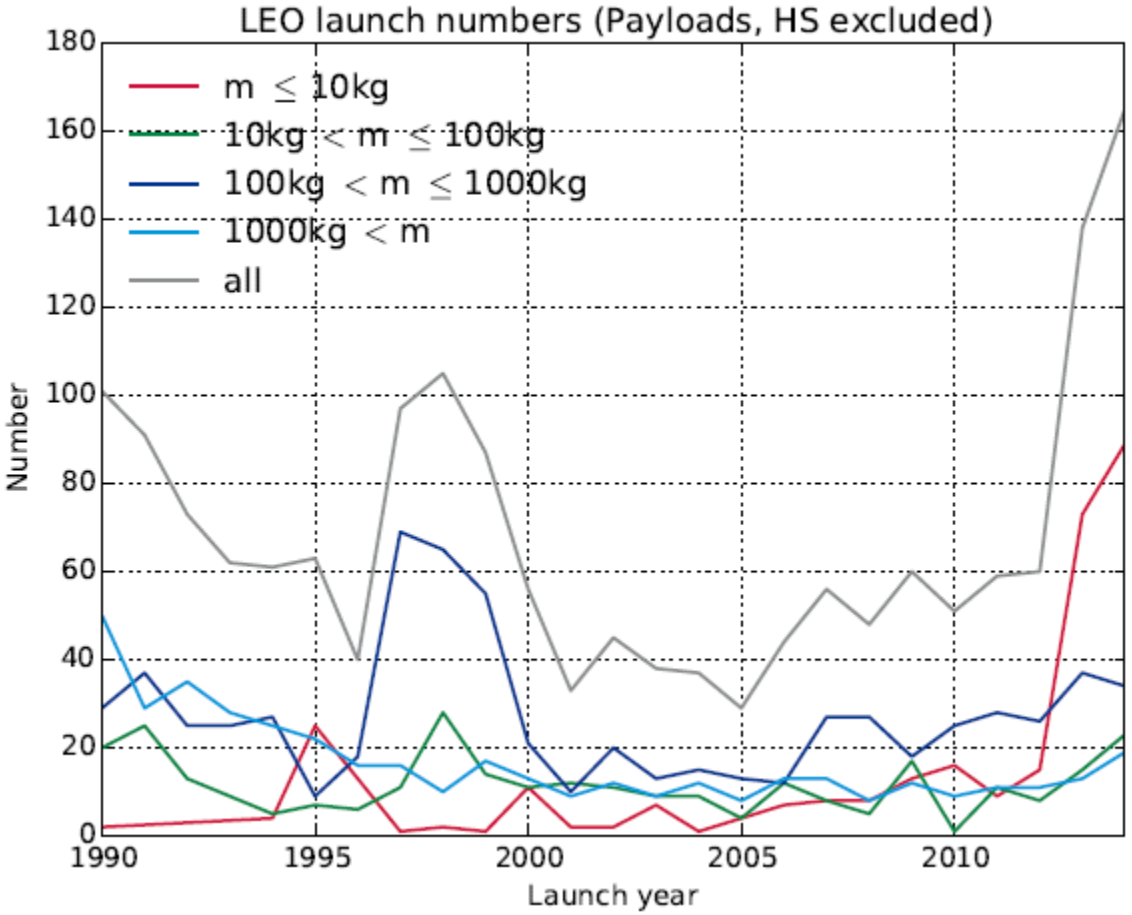
Increased Interest in Small Satellites



Year	m ≤ 10kg	10 < m ≤ 100kg
2011	9	11
2012	15	8
2013	73	15
2014	89	23

Constellations foreseen with 100-1000 satellites (e.g. KickSat-2, OneWeb, Flock)

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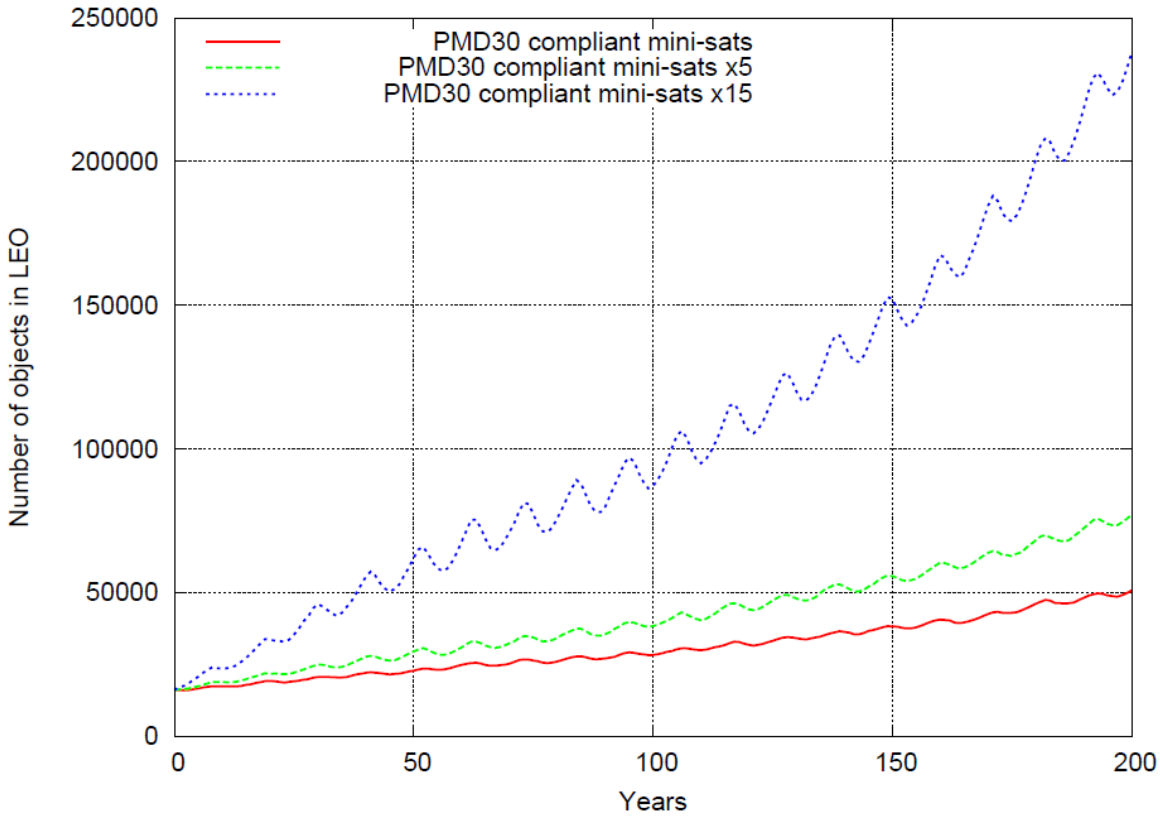
Effects of Small Satellites (1/2)

1. Analysing effect of the increased number of small satellites on the future LEO environment with the Debris Environment Long-Term Analysis tool (DELTA)
2. Scenarios, assuming 8 year trend (~60, 30% compliance) for mid-size to big satellites and varying number for small (assuming 100% compliance) satellites:
    a. ~130 satellites in LEO/year, corresponding to the 2 year trend of about 70-80 compliant small satellites
    b. 5x increased number of small satellites (~430)
    c. 15x increased number of small satellites (~1250)

Effects of Small Satellites (2/2)

1. Despite full compliance, the increased number of objects leads to an increased number of collisions
2. Increasing the number of launched small satellites by a factor of 15 leads to an exponential growth of objects in LEO



Conclusions

1. For small satellites with no OCC, the target orbit needs to be carefully selected so they decay naturally within 25 years
2. Currently ~70% of nano satellites (m ≤ 10kg) and ~30% of small to mid-size satellites (10 < m ≤ 1000kg) are compliant
3. If new traffic trends become the new normal, current guidelines might not be adequate anymore
4. Passive traceability can be improved via laser retro-reflectors or radar tuned wires (w/o substantially increasing the mass)
5. Engineering support for compliance analysis is available under https://sdup.esoc.esa.int/