

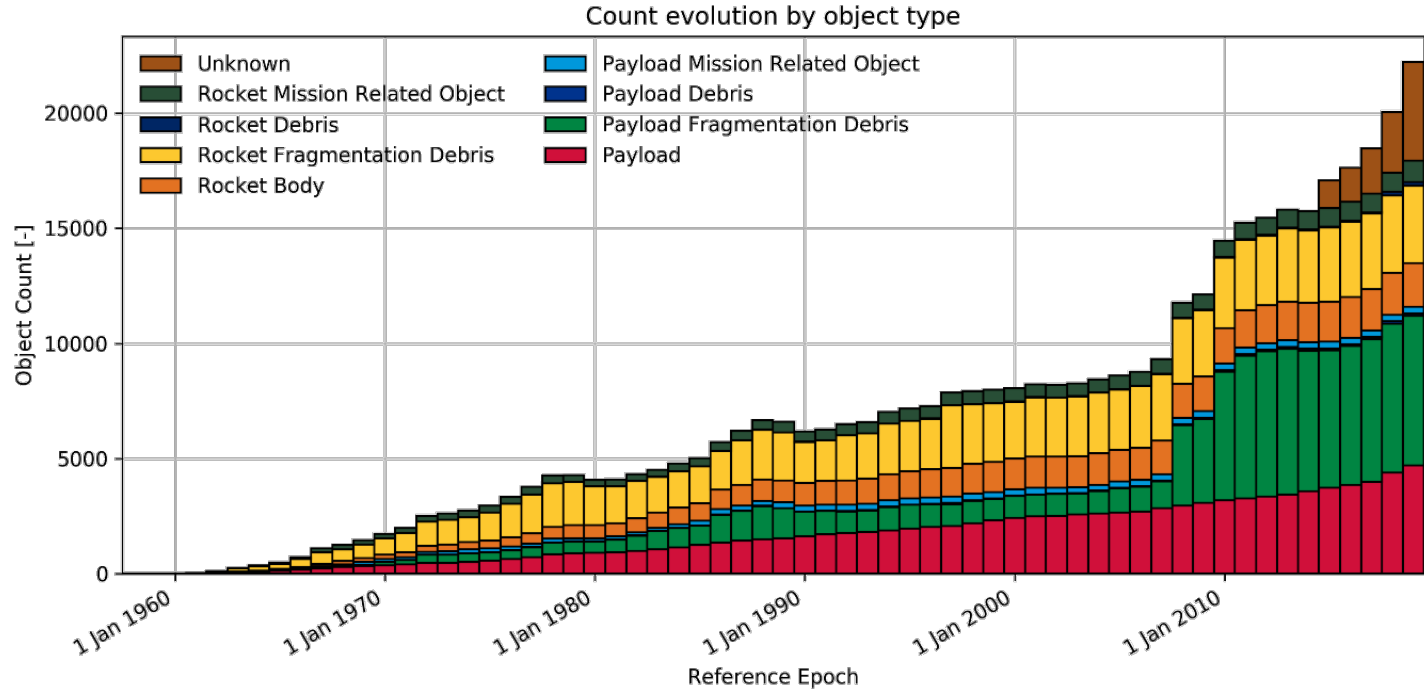
Space debris mitigation in practice

Stijn Lemmens

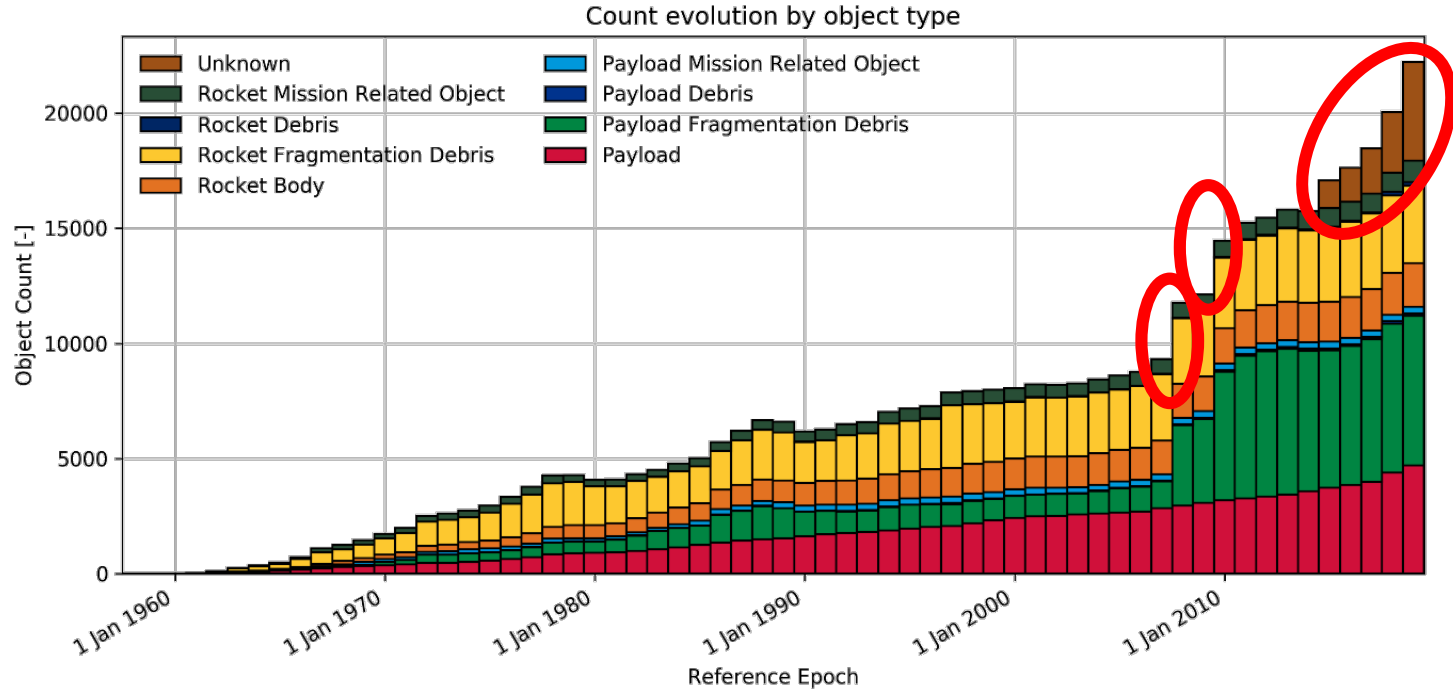
2019-03-20 ESA ECSL Workshop - Standards

- Guidelines and standards are only useful when they are used.
- United Nations, *Guidelines for the long-term sustainability of outer space activities (A/AC.105/2016/CRP.17)*, 2016. Guideline 26:
 - **Provide a transparent overview of global space activities,**
 - **Quantify the effect of internationally endorsed mitigation measures aimed at sustainability of the environment,**
 - Estimate the impact of these activities on the space environment.
- https://www.sdo.esoc.esa.int/environment_report/

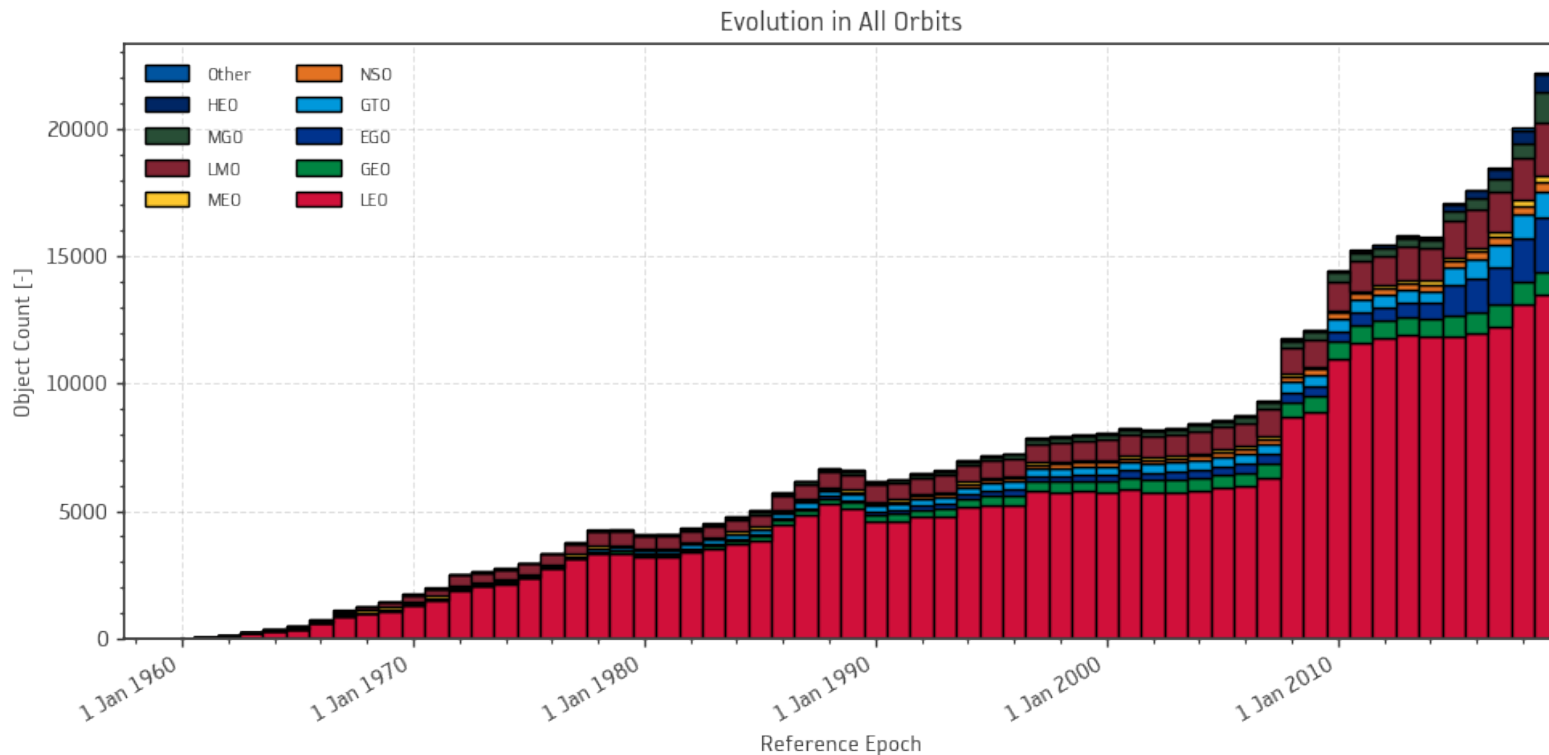
Space environment (tracked)



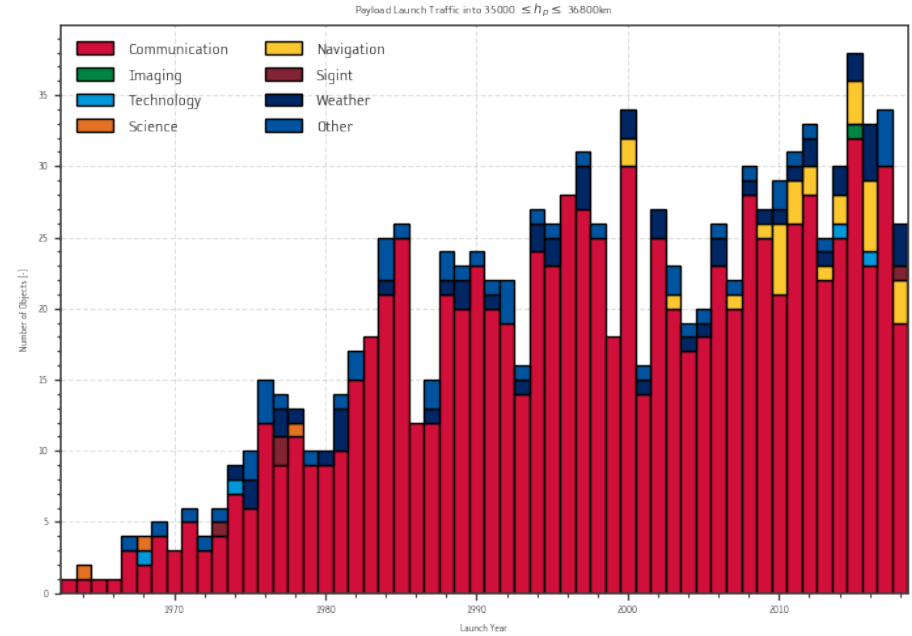
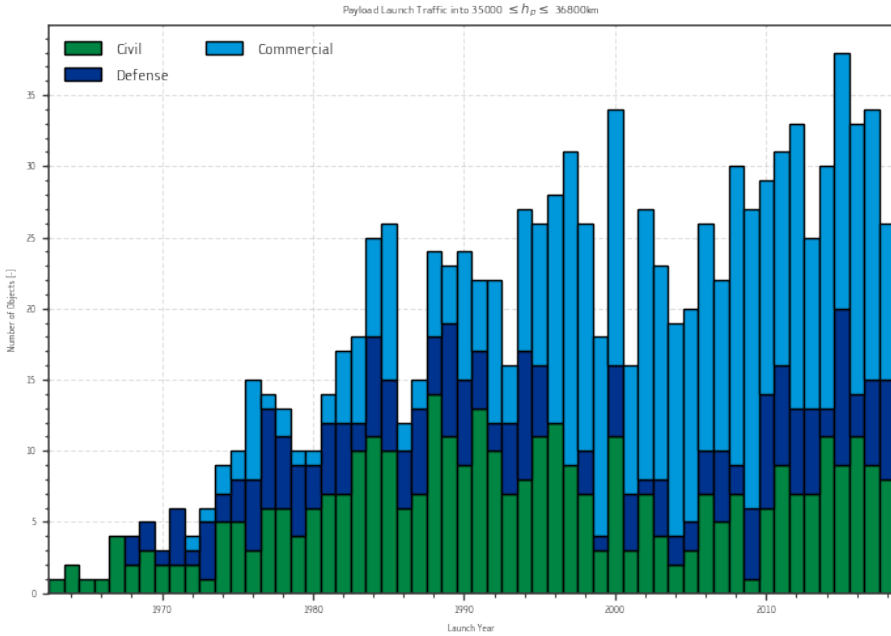
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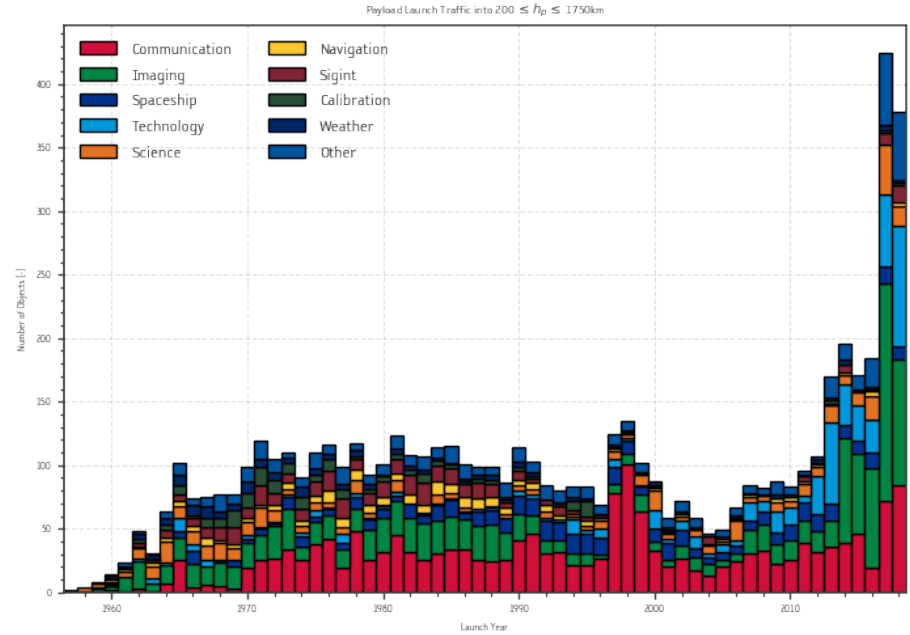
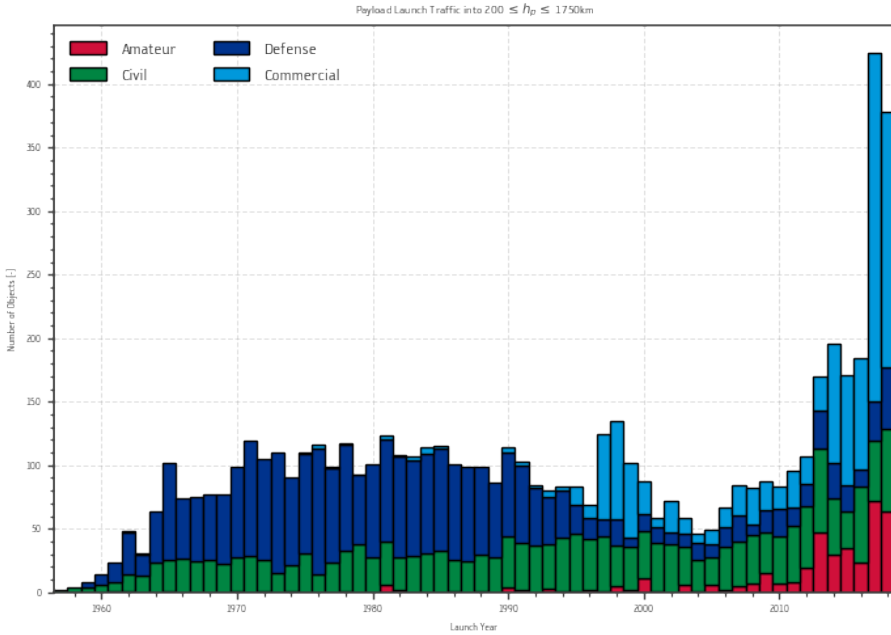
Space environment (tracked)



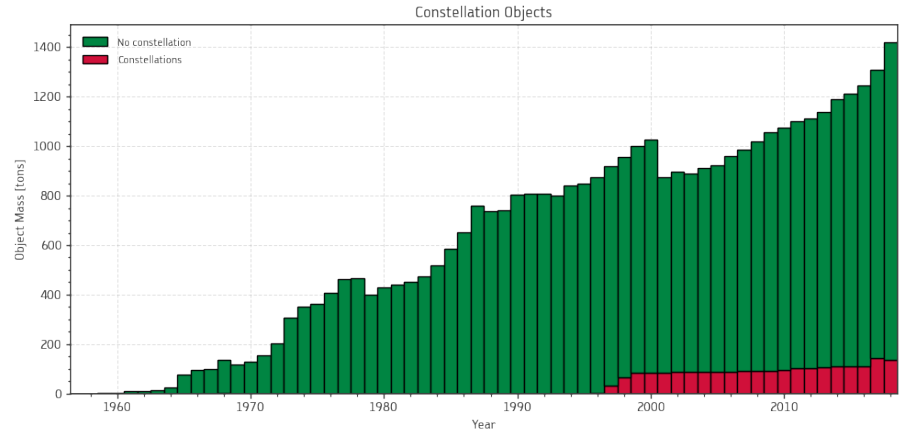
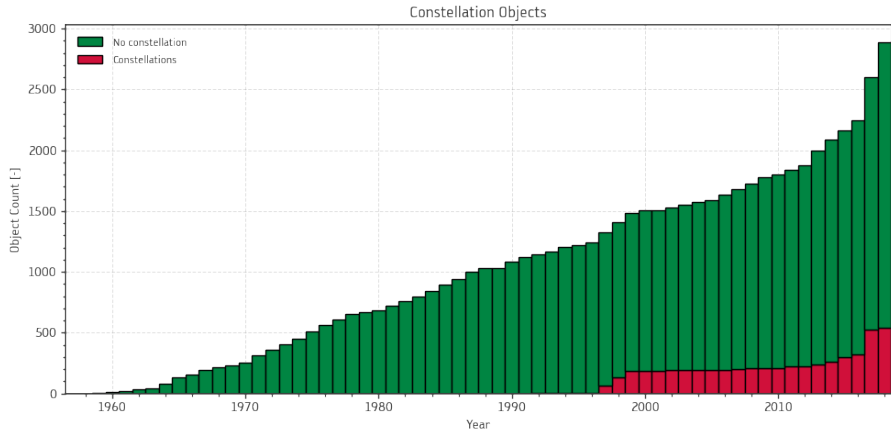
Space environment: GEO activity



Space environment: LEO activity



Space environment (Constellations LEO)



The Effect of space debris mitigation



- Statistics based **only** on what can be **observed** (estimates)
- No information on designer nor operator
- Lifetime assessment based on a ISO standards

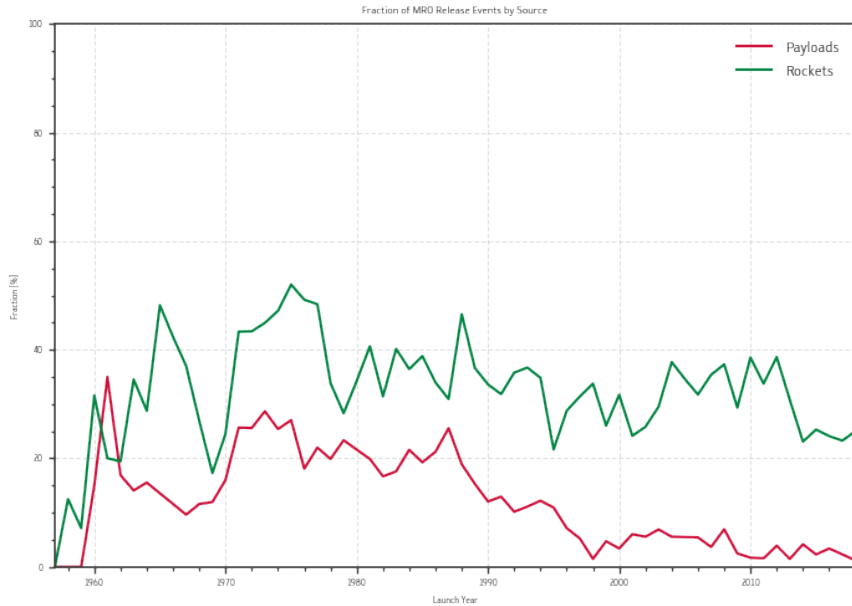
Evaluation of the IADC guidelines:

- The limitation of space debris released during normal operations;
- The minimisation of the potential for on-orbit break-ups;
- Post mission disposal;
- (Prevention of on-orbit collisions;)

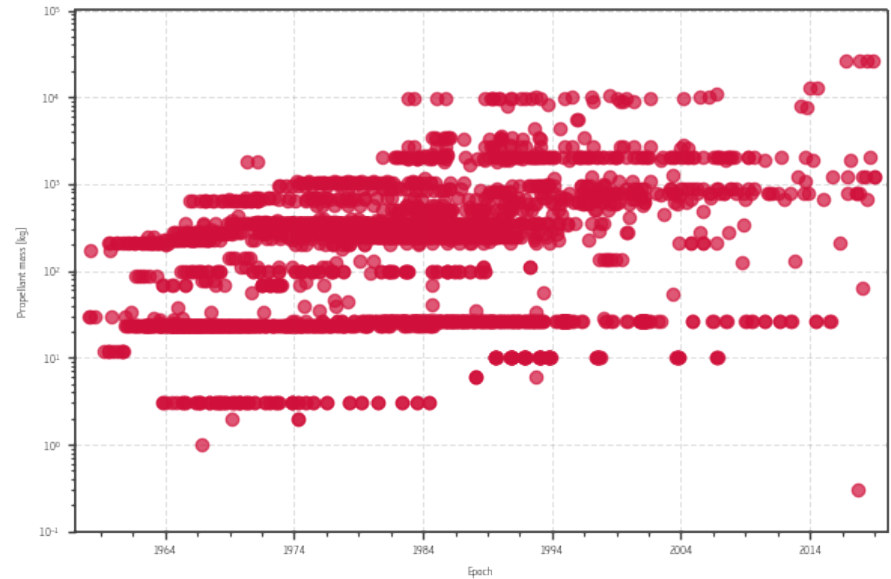


The effect: Intentional Release

Mission Object Release

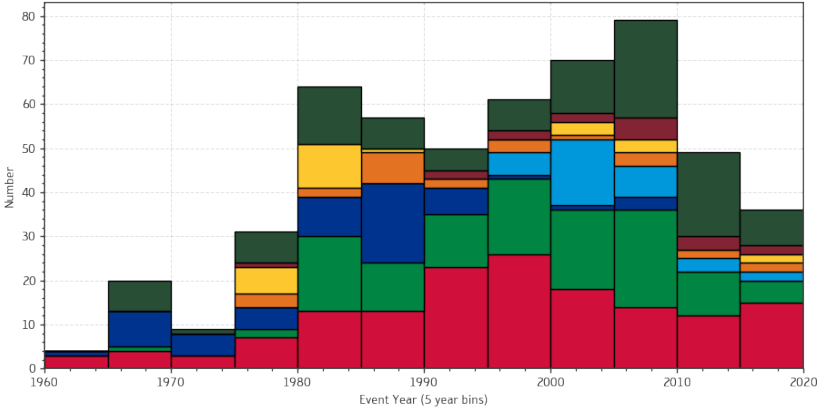


Solid Rocket Motor firings



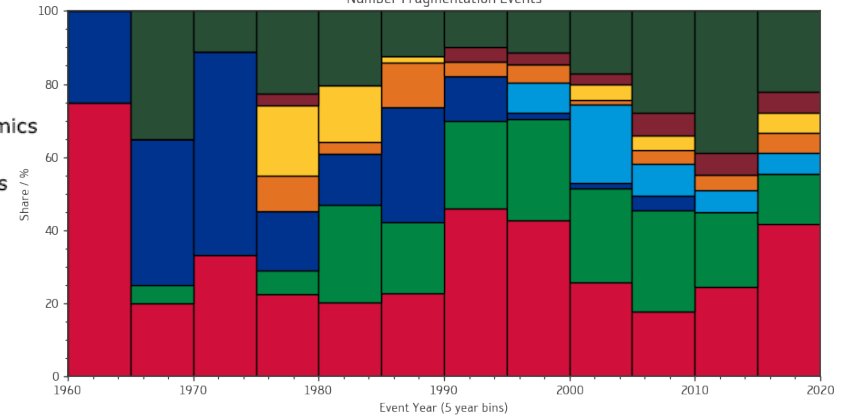
The effect: Fragmentations

Number Fragmentation Events



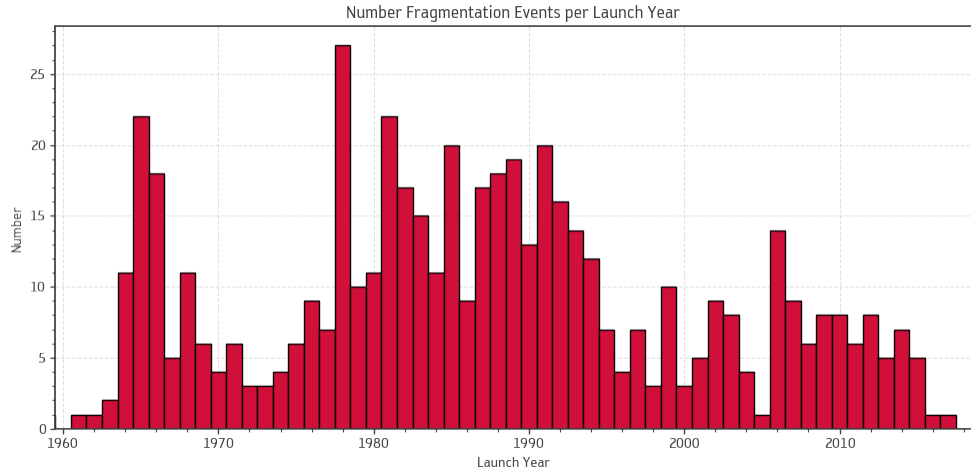
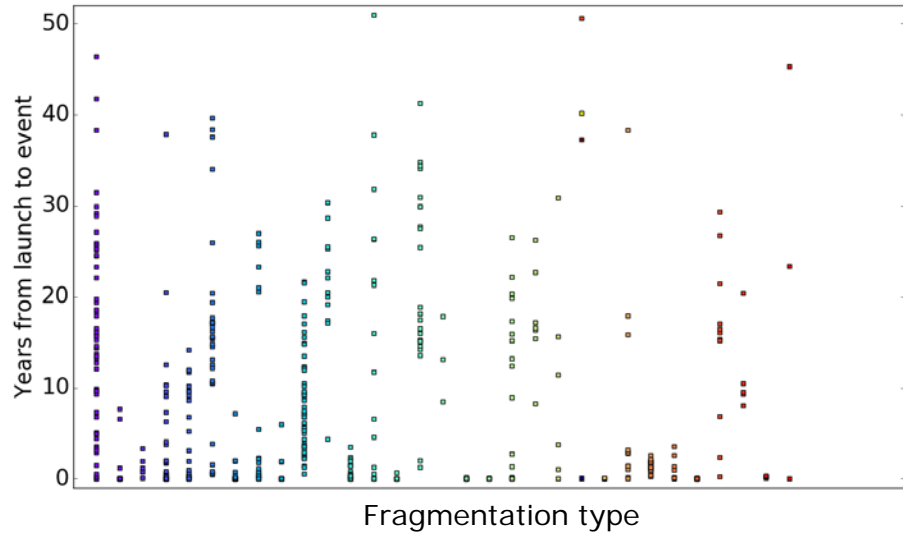
- Unknown
- Collision
- Electrical
- Accidental
- Aerodynamics
- Deliberate
- Anomalous
- Propulsion

Number Fragmentation Events

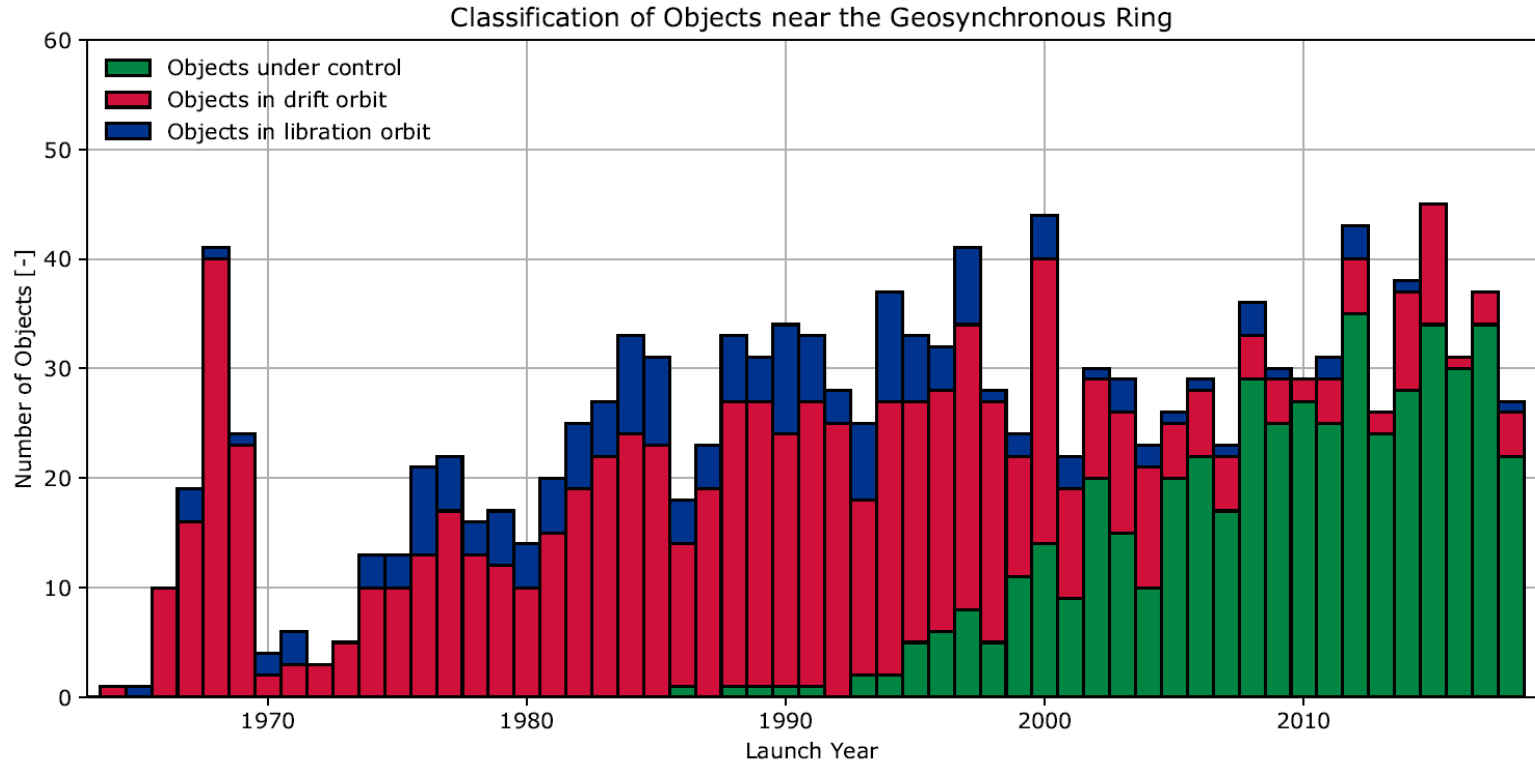


The effect: Fragmentations

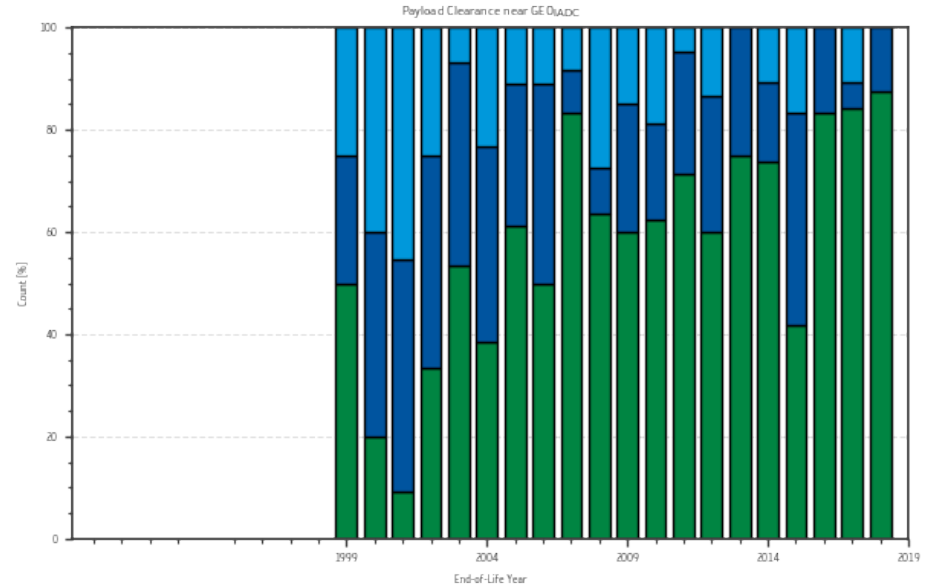
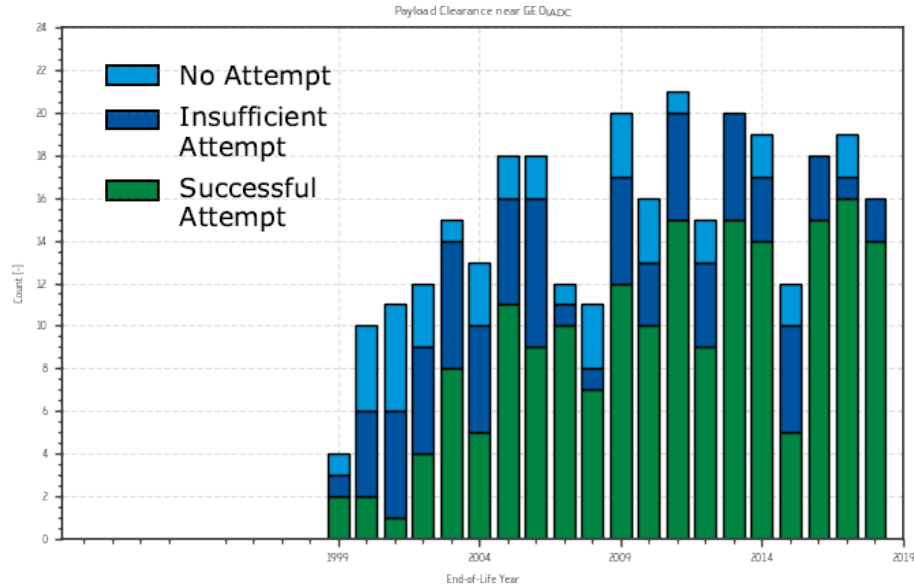
530 fragmentation events (246 in the last 20 years) are environmentally equal in that they should be avoided, but some are more equal than others



The effect: Post Mission Disposal GEO










The effect: Post Mission Disposal GEO

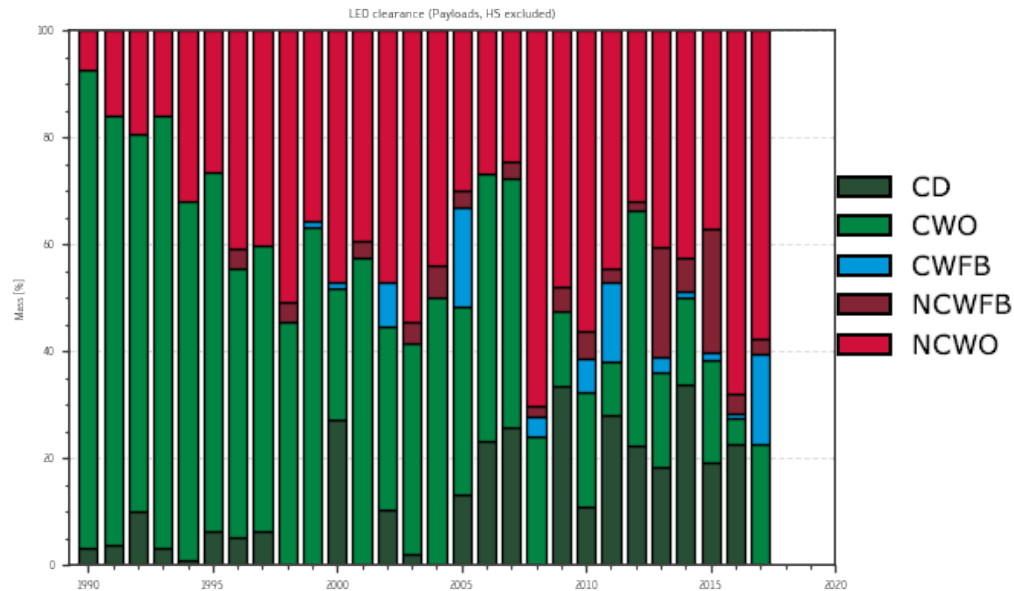
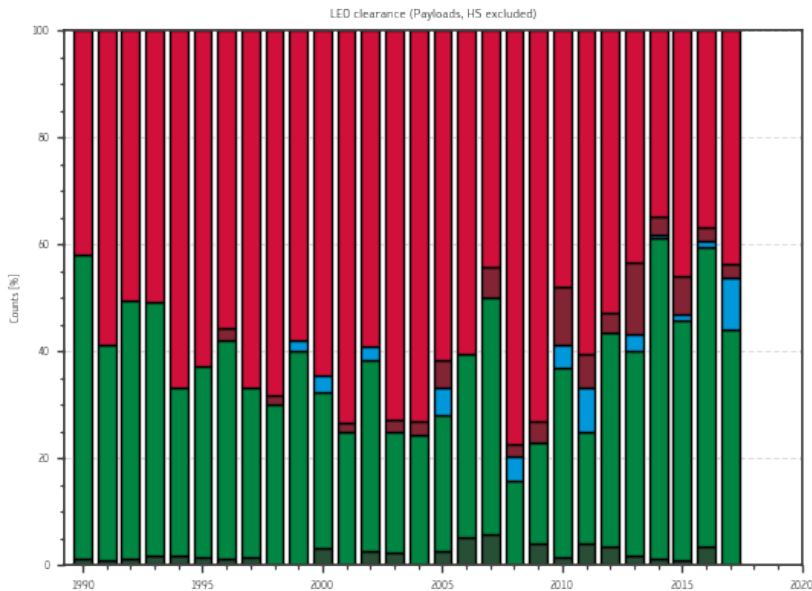


The effect: Post Mission Disposal



- CD:  Compliant with direct re-entry
- CWFB:  Compliant with attempt where the destination orbit would not have been compliant.
- CWTB:  Compliant with attempt where the destination orbit would have been compliant.
- CWO:  Compliant without an attempt.
- NCWFB:  Not compliant with attempt where the destination orbit would not have been compliant.
- NCWTB:  Not compliant with attempt where the destination orbit would have been compliant.
- NCWO:  Not compliant without an attempt.

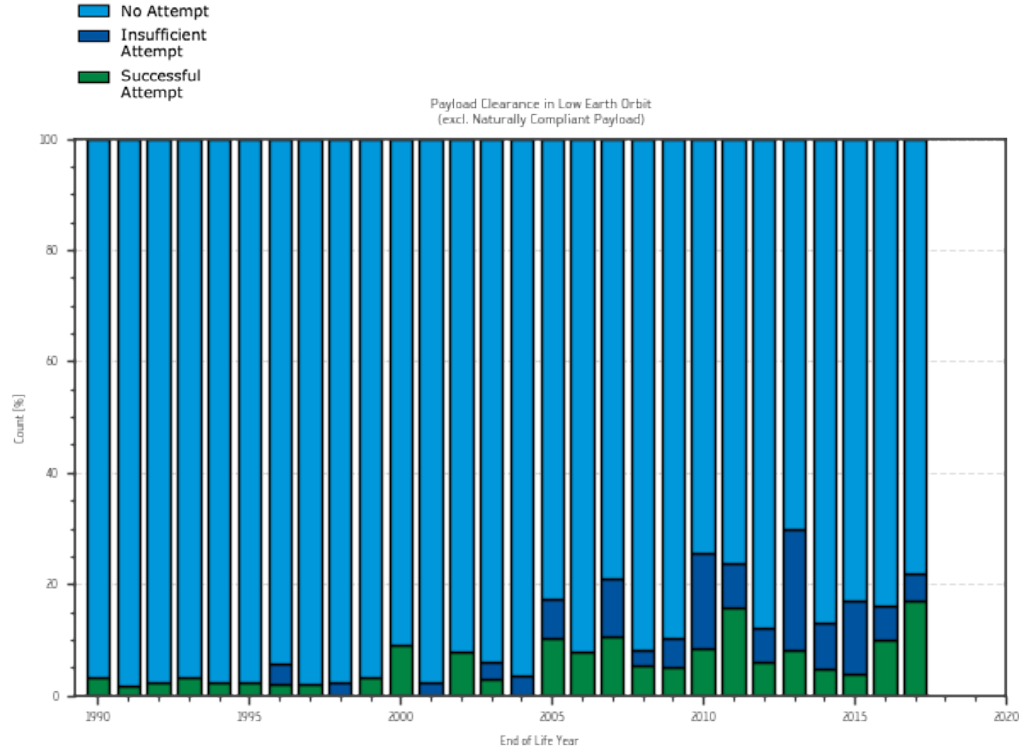
The effect: Post Mission Disposal (LEO, Satellites)



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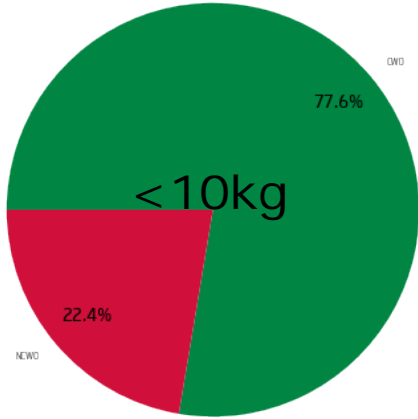
- Mission reliability at end of mission w.r.t. executing a disposal
 - From standards [80-90 %]
 - From (scares) observation [90-95 %]
- Required successful post mission disposals for environmental stability [90-100 %]
- Observed operational success [5-15%]



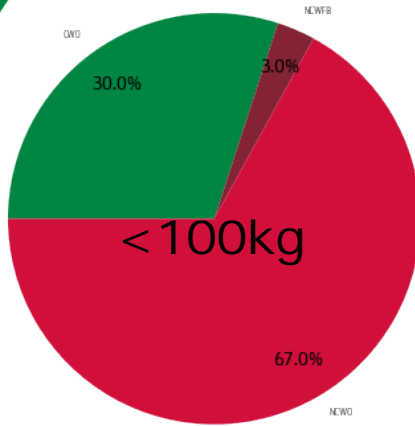
The effect: Post Mission Disposal (LEO, Satellites)



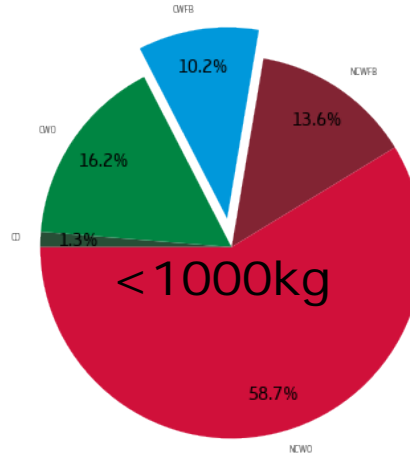
LEO compliances (Payloads w/o HS, EDL ≥ 2010, m ≤ 10kg)



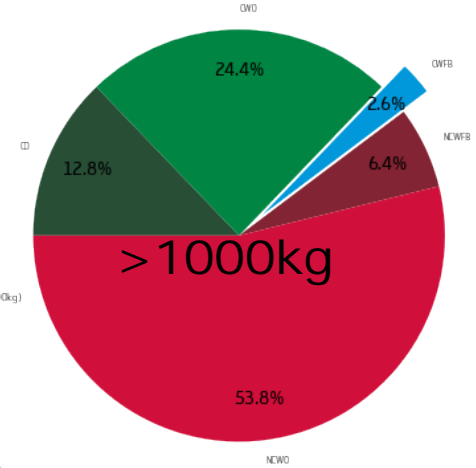
LEO compliances (Payloads w/o HS, EDL ≥ 2010, 10kg < m ≤ 100kg)



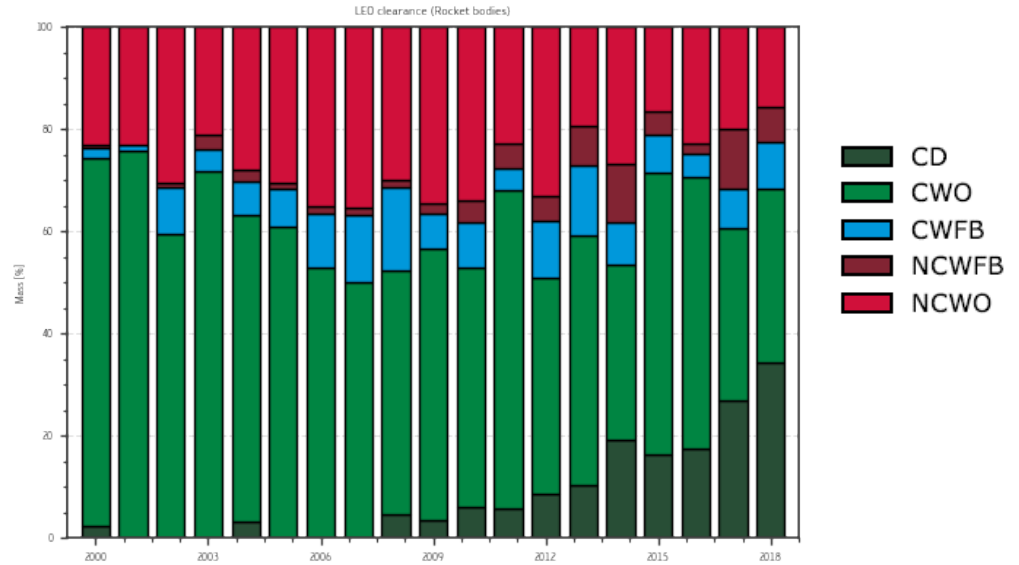
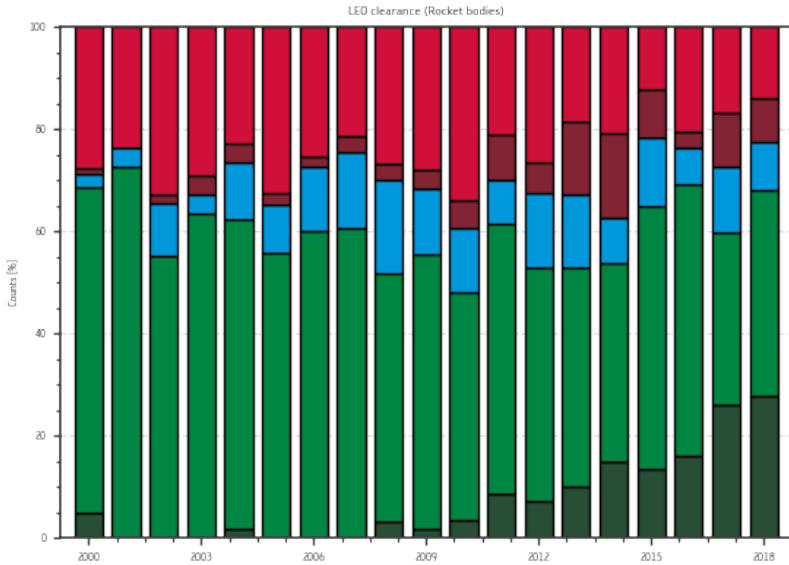
LEO compliances (Payloads w/o HS, EDL ≥ 2010, 100kg < m ≤ 1000kg)



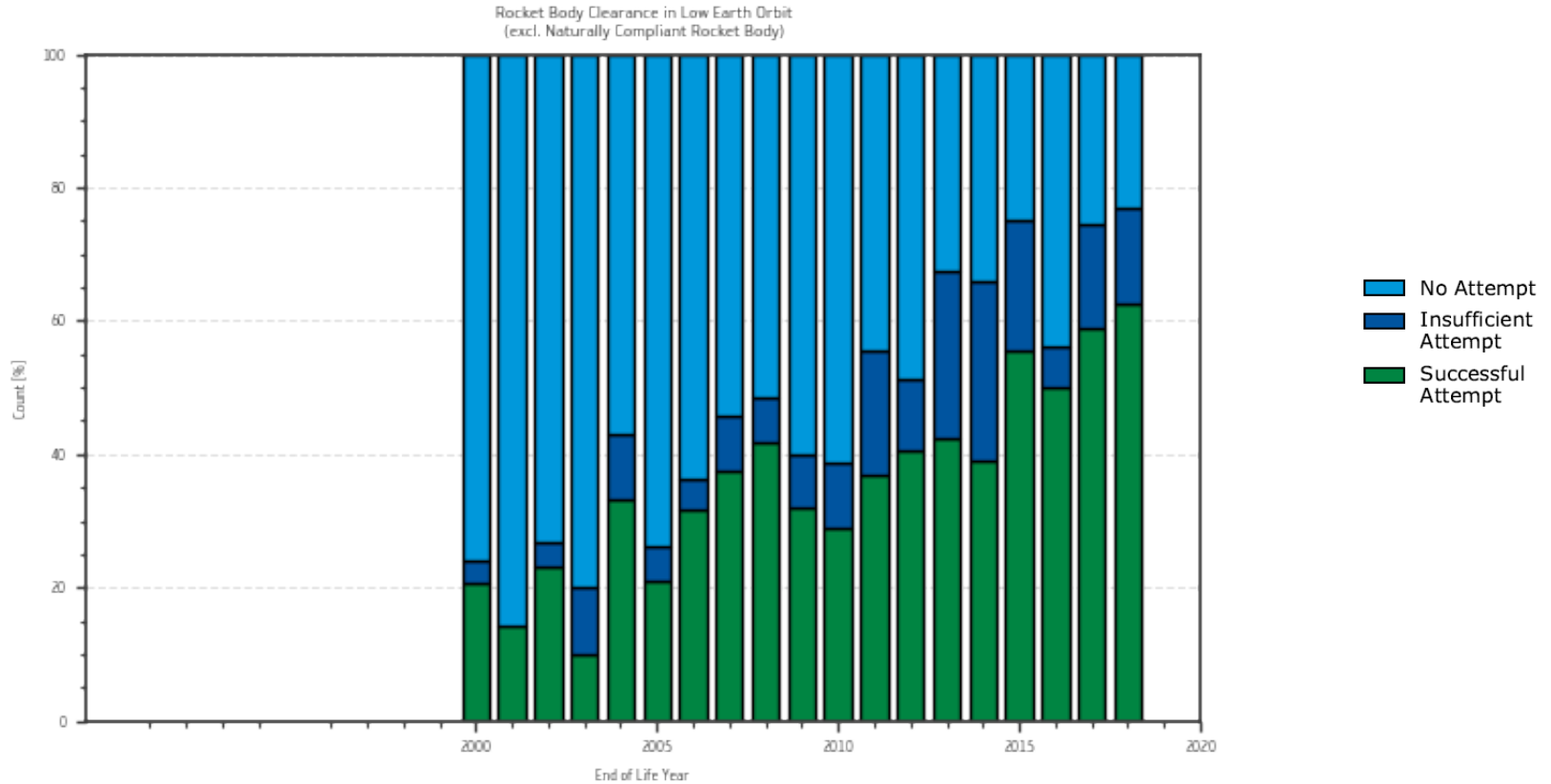
LEO compliances (Payloads w/o HS, EDL ≥ 2010, 1000kg < m)



The effect: Post Mission Disposal (LEO, Rockets)



The effect: Post Mission Disposal (LEO, Rockets)



- Launch traffic and stakeholders have changed and will continue to change
- On average 11.5 non-deliberate fragmentations / year (last 20 years),
 - 2.4 have 50% of the fragments with lifetimes above 25 year.
- On Payloads in LEO (this decade):
 - Around 80% of the small payloads are placed in compliant orbits.
 - Between 25 and 50% of all mass at EOL is in compliant orbits.
- On Rocket Bodies in LEO (this decade):
 - Around 70% of all mass at EOL is in compliant orbits (LEO).
 - Trend from delayed deorbit to controlled re-entry

- Around 10 to 20% of payloads in LEO attempt to comply at EOL
 - 5-15% success (including re-orbits)
- Around 50 to 70% of rocket bodies in LEO attempt to comply at EOL
 - 50% successful (including perigee raising)
- Around 90% of payloads in GEO attempt to comply at EOL
 - 80% successful)

- Behavior in space is learned and can be changed!