Space Debris Mitigation Activities at ESA in 2014

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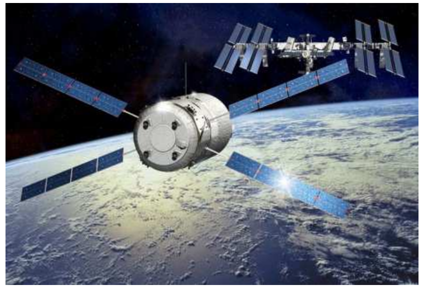
ESA Launches in 2014

- Sentinel-1A
  - Launch: April 3rd, 2014 from CSG/Kourou (Soyuz), 697km x 695km @ 98.7°
  - Mission: C-band Synthetic Aperture Radar Imagery
- ATV-5:
  - Launch: July 29th, from CSG/Kourou (Ariane 5), 408km x 401km @51.7°
  - Mission: Cargo supply to the ISS. Docking on: Aug 12th
- Galileo 5
  - Launch: August 22nd, from CSG/Kourou (Soyuz) , 25,966km x 17,232km @ 49.7°
  - Degraded injection, perigee raising by ca. 3500km
- Galileo 6
  - Launch: with Galileo 5, 25,918 km x 13,810km @ 49.7°
  - Degraded injection, orbit raising attempt



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Requirements and Handbooks

Agency Debris Mitigation Requirements

- Since April 2014, ISO-24113 has replaced the “Requirements on Space Debris Mitigation for ESA Projects”
    - applicable ECSS standard (ECSS-U-AS-10C issued on 10 February 2012) that endorses and tailors ISO-24113
- Areas of tailoring:
    - Release of 1 mission related object for the launch of multiple payloads
    - Solid rocket motor combustion products > 1mm
- Space Debris Mitigation Handbook
    - Detailed compliance verification guidelines
    - Accurate description of options and models to be used
    - Expected release 2nd quarter 2015

g. Fragment impact kinetic energy

h. Fragment impact location (latitude, longitude) for deterministic simulations (for global distribution of all fragments, see Re-entry Casualty Area Determination, sect. D.2.13)

i. Fragment Floating/non-floating capability over water/oceans.

D.2.11 Fragment Casualty Area

The casualty area of a surviving fragment ($A_{c,k}$) leading to a casualty if a person is struck, conventionally with impact kinetic energy greater than 15 J (e.g. [RD3]), is defined as (Figure D-6):

$$A_{c,k} = \left[\sqrt{A_{i,k}} + \sqrt{A_h}\right]^2 \qquad [C-20]$$

where:

A_i maximum projected area of the fragment surviving the re-entry

A_h cross-section of a human, which is conventionally defined equal to 0.36 m² according to the NASA Safety Standard NSS 1740.14

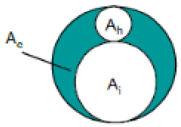

Figure D-6: Casualty area definition

D.2.12 Total Casualty Area

The total casualty area (A_c) for the re-entry is the sum of the casualty area of all surviving fragments ($A_{c,k}$):

$$A_c = \sum_{i=1}^{N} A_{c,k} \qquad [C-21]$$

D.2.13 Casualty Expectancy

Risk is an undesirable situation or circumstance that has a likelihood of occurring and a potential negative consequence. Re-entry casualty risk is determined through the probability to cause serious injury or death. As a probability, the risk is by definition ≤ 1. Since the variable number of casualties (N) is discrete and the computation of the probability implies a sum (integration) over the space over which the probability is distributed, this corresponds to the expected number of casualties ($E = N$), i.e. to an expectancy which could even allow values > 1. The computation of the risk profile requires knowledge on the underlying (discrete) probability distribution function, which is difficult to determine. If the probability (P).of at least one casualty needs to be lower than a given value it is not

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The DRAMA 2.0 Software Suite

ARES: Assessment of Risk Event Statistics:

- To consider the possible requirements for collision avoidance manoeuvres during a mission.

MIDAS: MASTER (-based) Impact Flux and Damage Assessment Software:

- To model the collision flux and damage statistics for a mission.

OSCAR: Orbital Spacecraft Active Removal:

- To analyse the disposal manoeuvre performed by a space system at the end of its useful lifetime.

CROC: Cross Section of Complex Bodies

- To compute projected cross-sectional areas of complex bodies

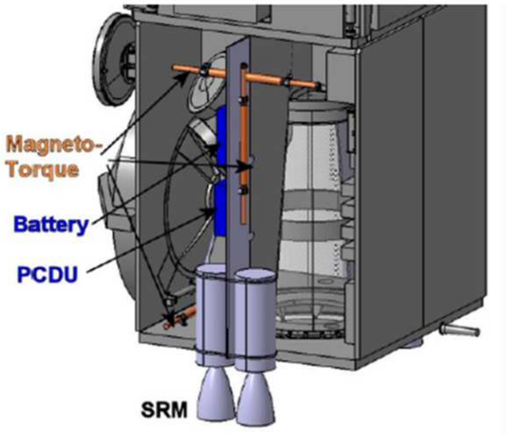
SARA: Re-entry Survival and Risk Analysis

- To model the re-entry of a space system into the Earth's atmosphere.
- To assess the risk on-ground of objects surviving re-entry.

Cleanspace Technology for Mitigation

1. **Design for Demise** to ensure break-up during the atmospheric re-entry
2. **Passive de-orbiting** particularly for small S/C, especially those without propulsion system
3. **Active de-(re)orbit devices** for larger satellites
4. **Passivation of power and propulsion systems**, advanced passivation methods for current and future missions shall be identified

- **CleanSat:** Evolution of LEO platforms to comply with SDM requirements



Solid **P**ropellant **A**utonomous **De**-orbit **S**ystem

Accomodation on LEO Satellite

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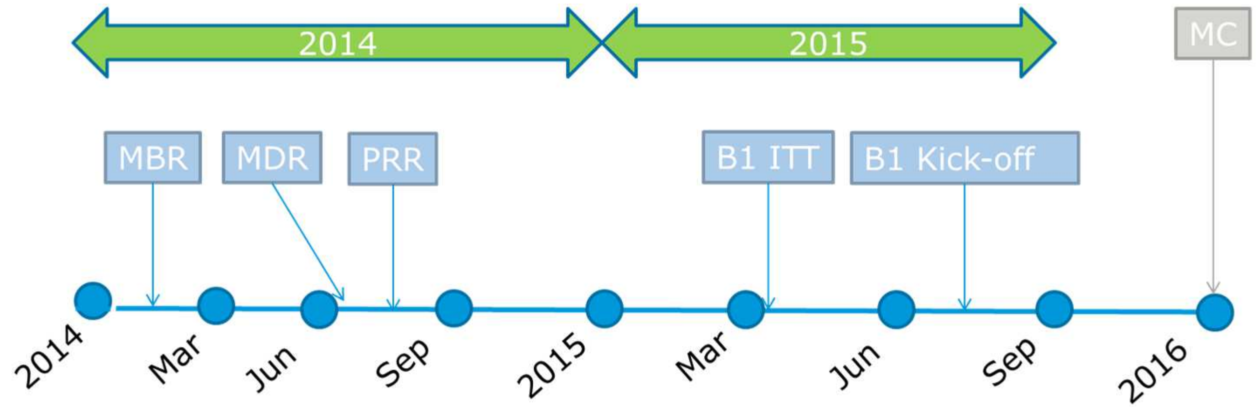
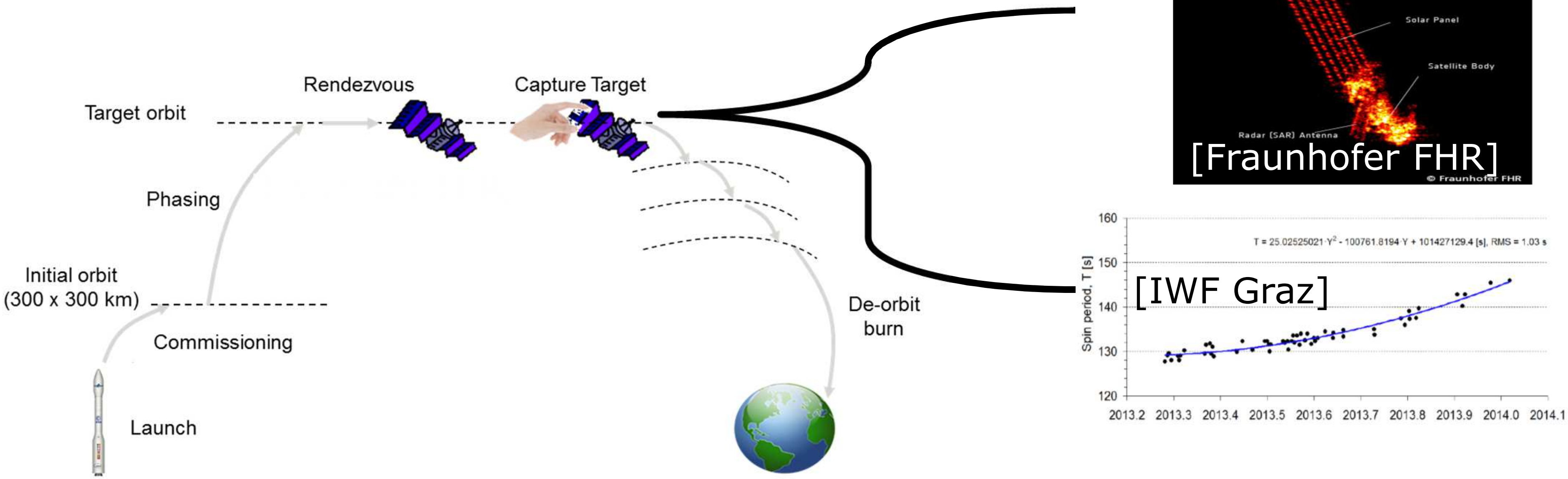
Active Removal: e.Deorbit Phase-A





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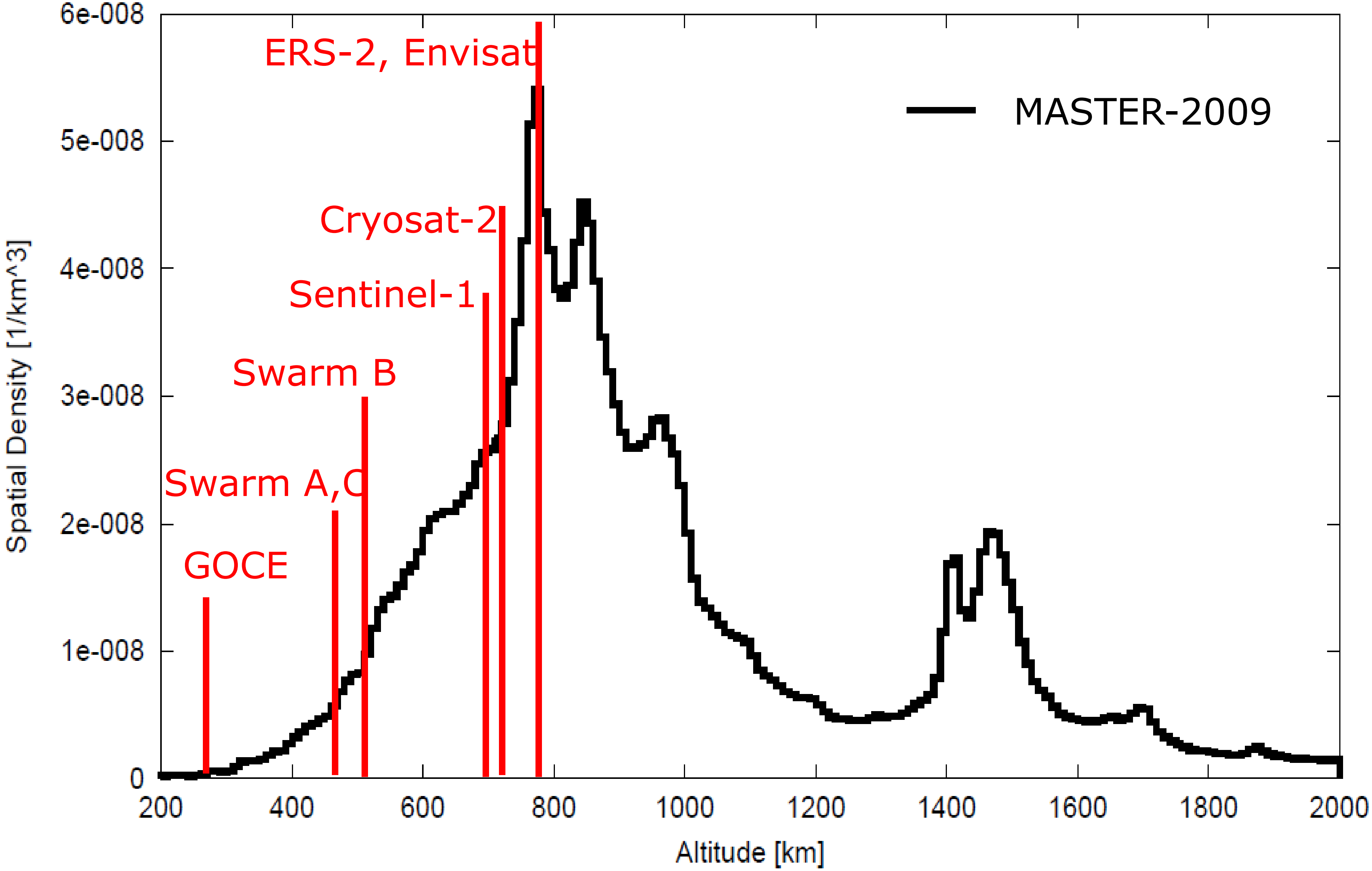
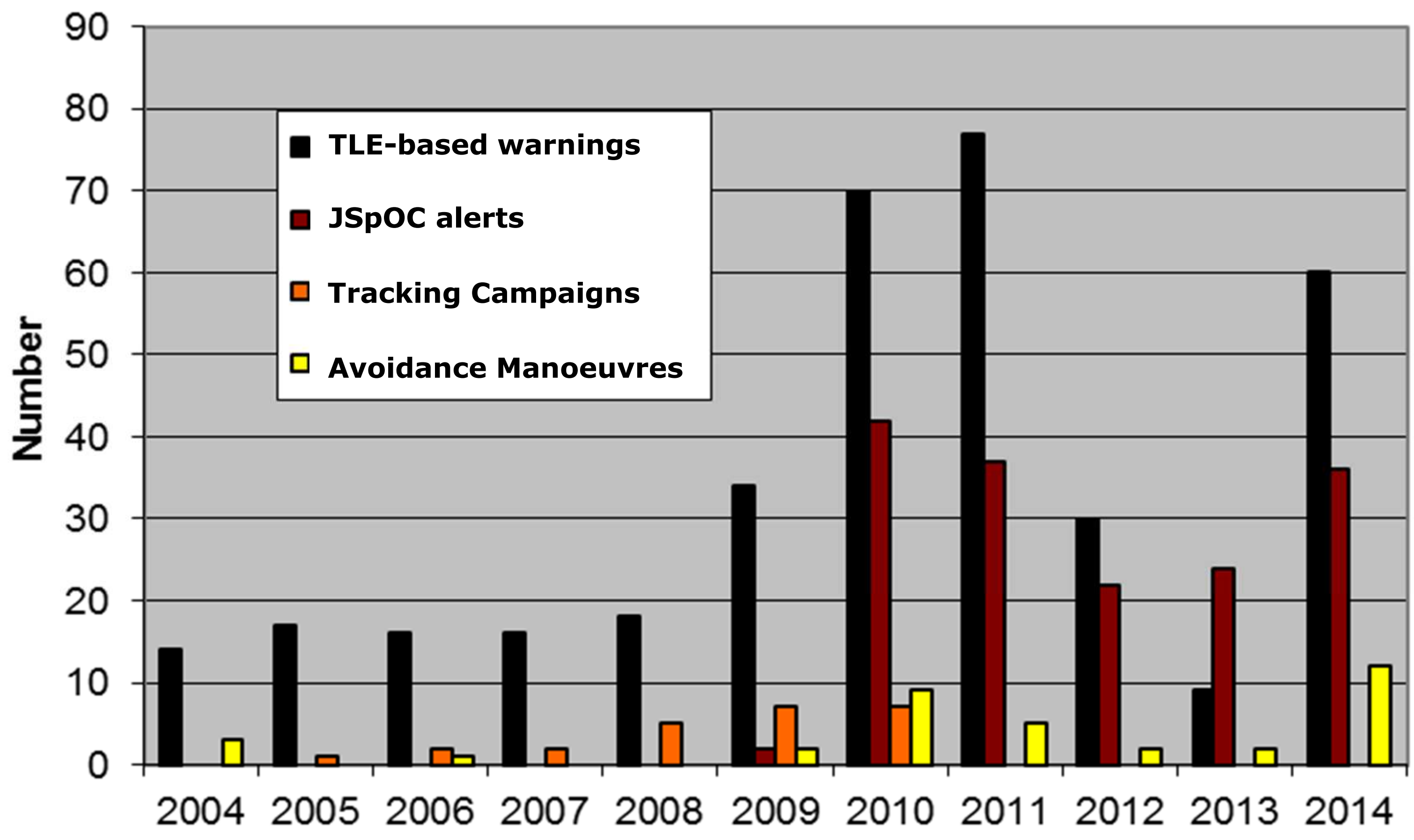
Current Environment of Objects > 10cm



Conjunction Event Statistics



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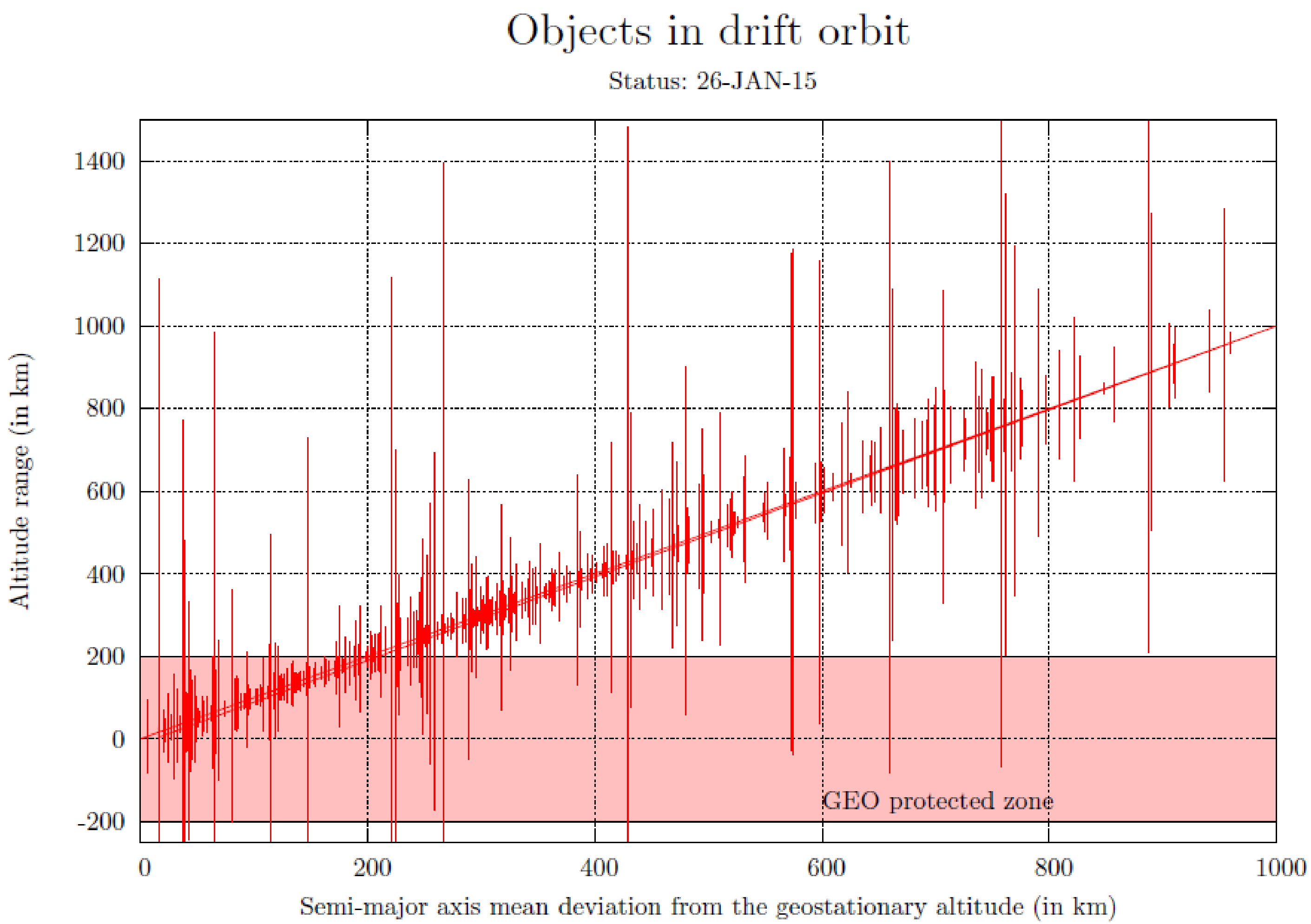
GEO: Current Status (objects with TLEs)



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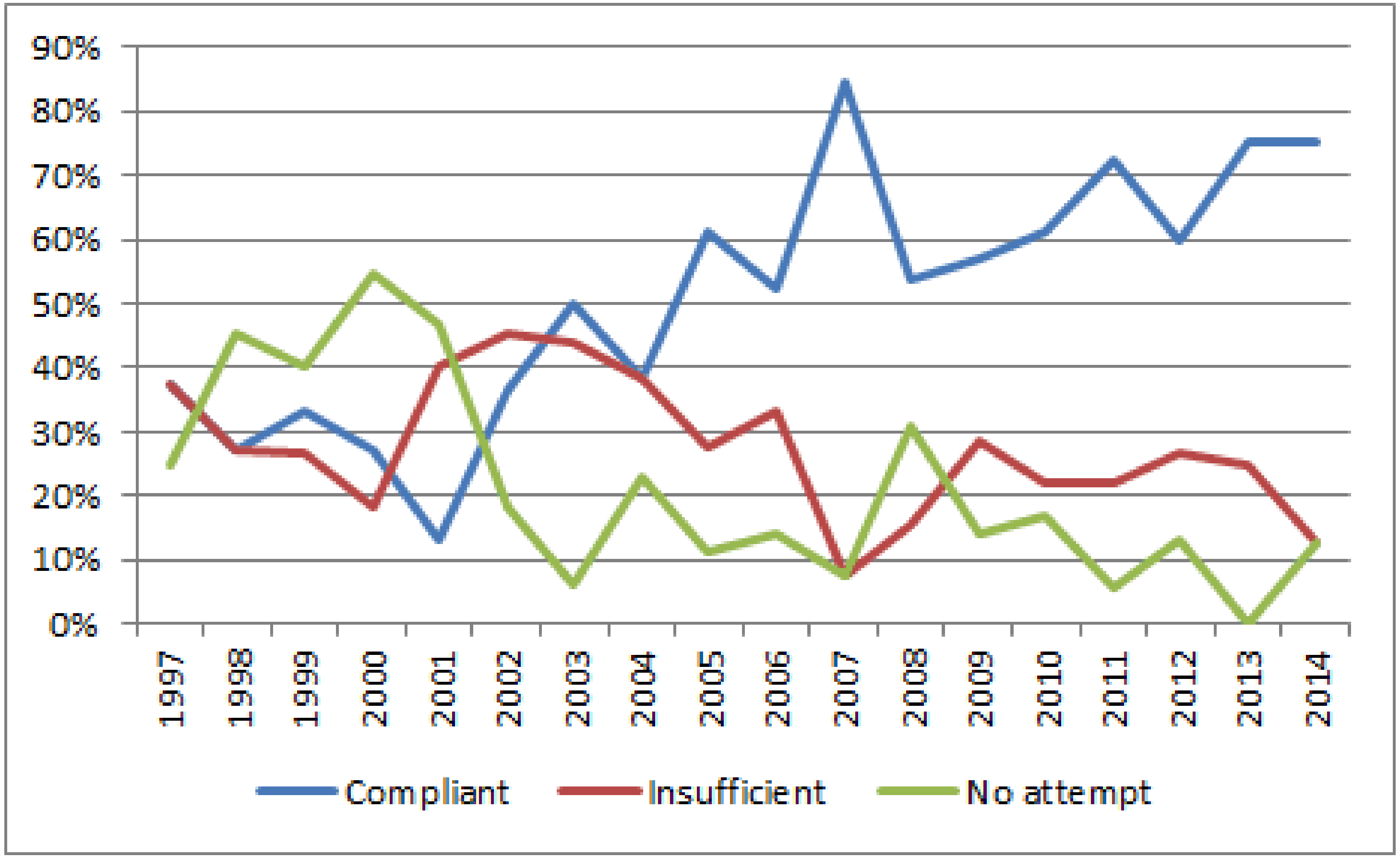
GEO protected zone: EoL Statistics

- Average of 16 annual disposals (results for 2014 still under consolidation)
- based on Surveillance data and (where available) operator confirmation



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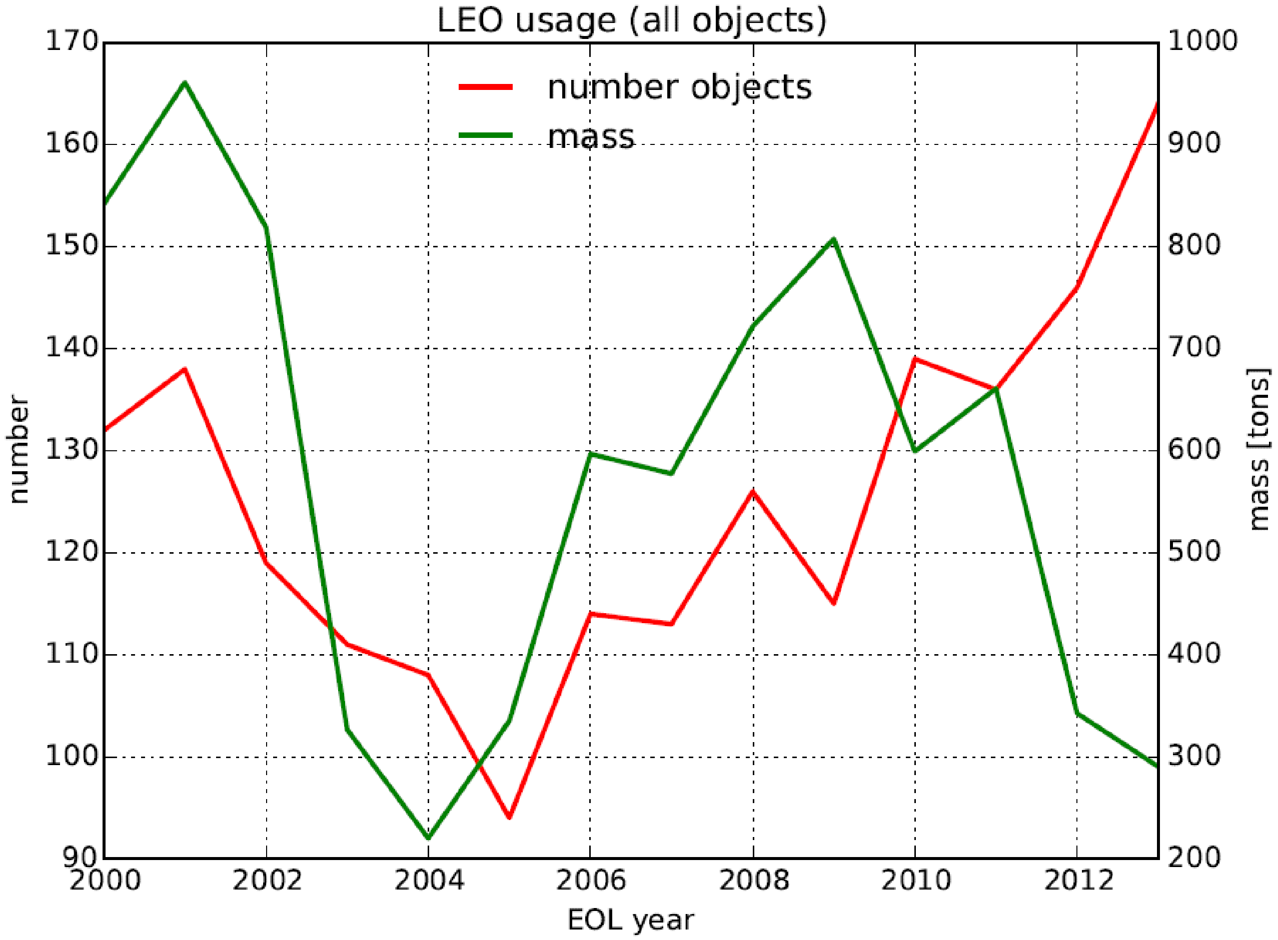
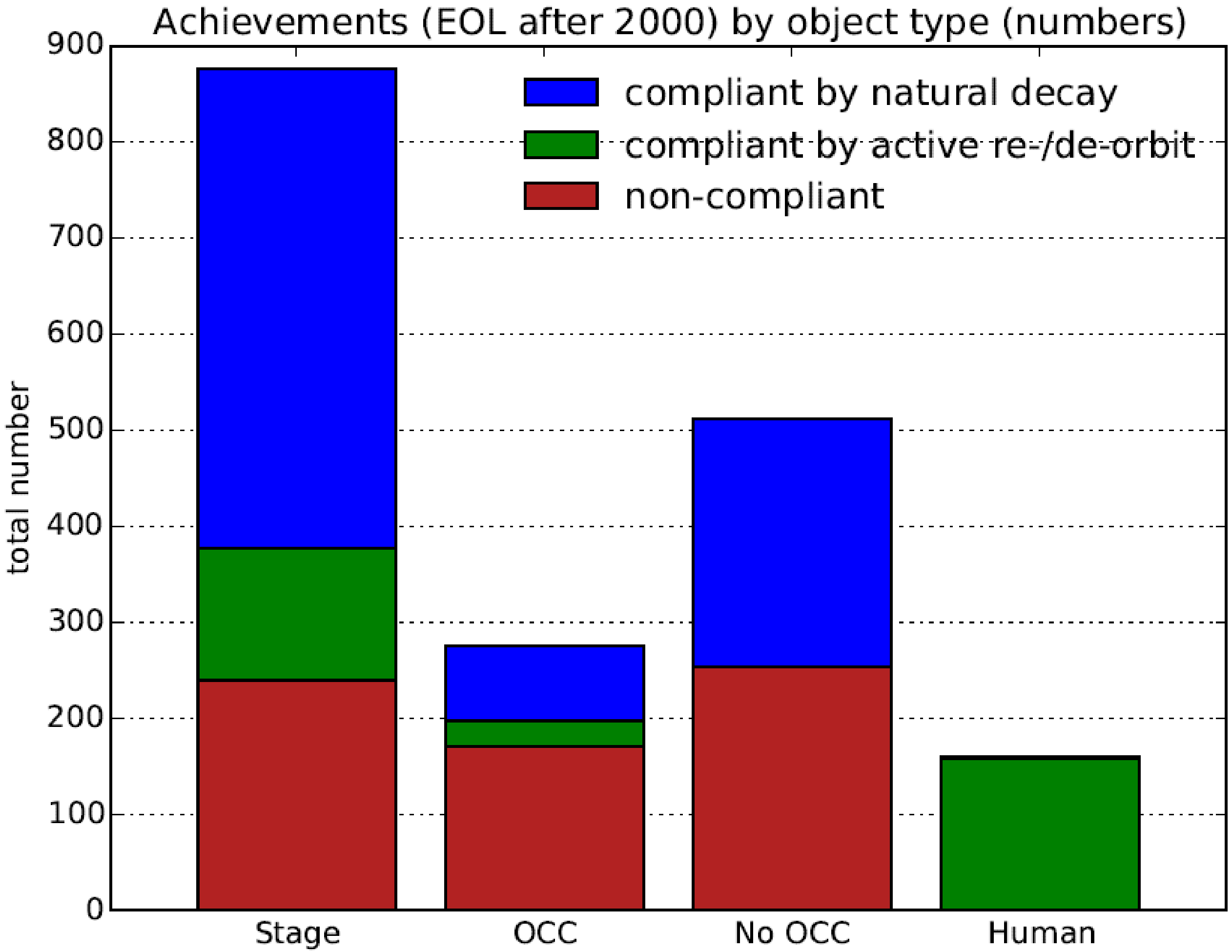
LEO: Objects reaching EoL

- based on surveillance data, end-of-activity (manoeuvre) detection, orbital lifetime predictions, statistical lifetime estimations for non-manoeuverable objects



LEO Clearance 2000-2012 by Type



OCC= Orbit Control Capacity

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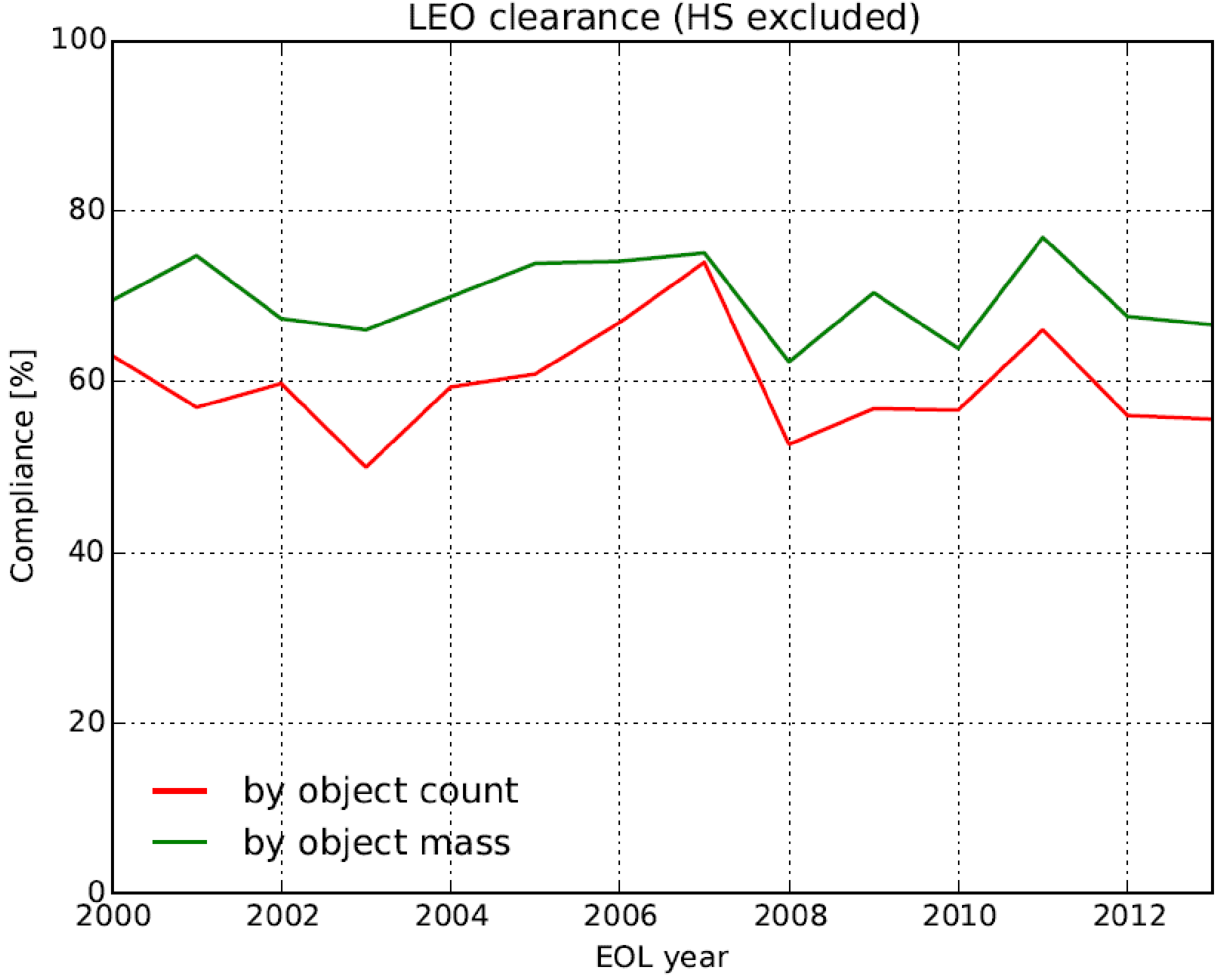
LEO Summary Trend: All Objects

- Objects associated with human spaceflight (HS) excluded here



Summary

- ESA benefits from a new US-ESA Agreement under which we receive accurate orbit and covariance information
- ESA has endorsed ISO-24113 and made it applicable to ESA missions
- Global performance in mitigating debris:
    - a clear and positive trend in GEO
    - Poor in critical LEO altitudes, no apparent trends
- ESA has enforced its efforts by providing adequate guidance and tool support
- ESA invests into technology to support mitigation actions and active removal