Re-entry analysis comparison with different solar activity models of spent upper stage using ESA's DRAMA tool

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February 2012 one tank of Ariane 4 crashes in a Brazilian village

ONE STUDY- TWO GOALS

OSCAR

- Providing a tool for the verification of end-of-life disposal strategies
- **Goal:** Demonstrate OSCAR properties for GTOs

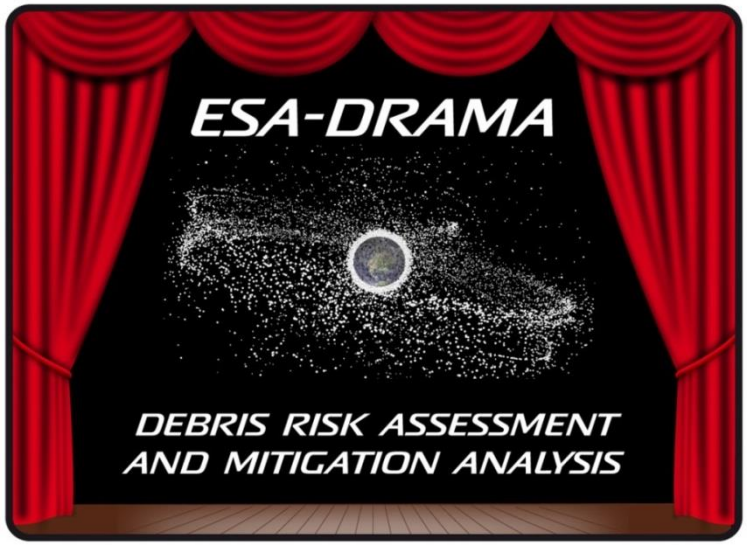
Rocket Upper Stage in GTO

- Understand evolution in GTO in order to prepare future missions (choice of Ariane 4 because similar orbit and it re-entered)

- Particularity of GTO (Resonance effects, Low perigee)

OSCAR (Orbital SpaceCraft Active Removal)

- Part of ESA‘s **DRAMA** (**D**ebris **R**isk **A**ssessment and **M**itigation **A**nalysis) tool suite
- Other tools: ARES, MIDAS, CROC, SARA
- Simulation and evaluation of end-of-life disposal strategies



- Future solar and geomagnetic activity
  - ISO 27852:2011 (lifetime estimation)
  - ECSS-E-ST-10-04C (space environment)
- Different disposal systems
  - Chemical propulsion
  - Electric propulsion
  - Electrodynamic tether
  - Drag augmentation
- Compliance criteria wrt. the UN Space Debris Mitigation Guidelines

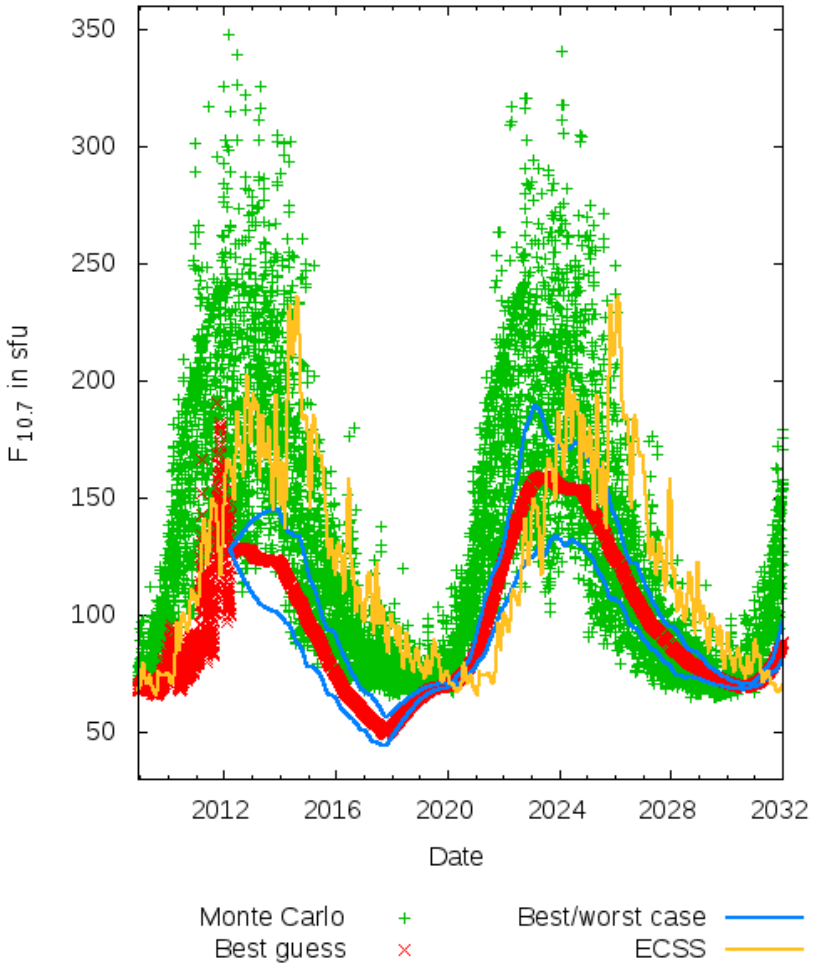
Solar & geomagnetic activity

- Five different forecast methods selectable

- Based on recent standards

1. Best guess (McNish-Lincoln, ISO)
2. Best case / worst case
3. Repeatable cycle (ECSS)
4. Constant cycle (French Space Operation Act)
5. Monte Carlo (ISO)

- Using up-to-date space weather data for best guess approach



Question

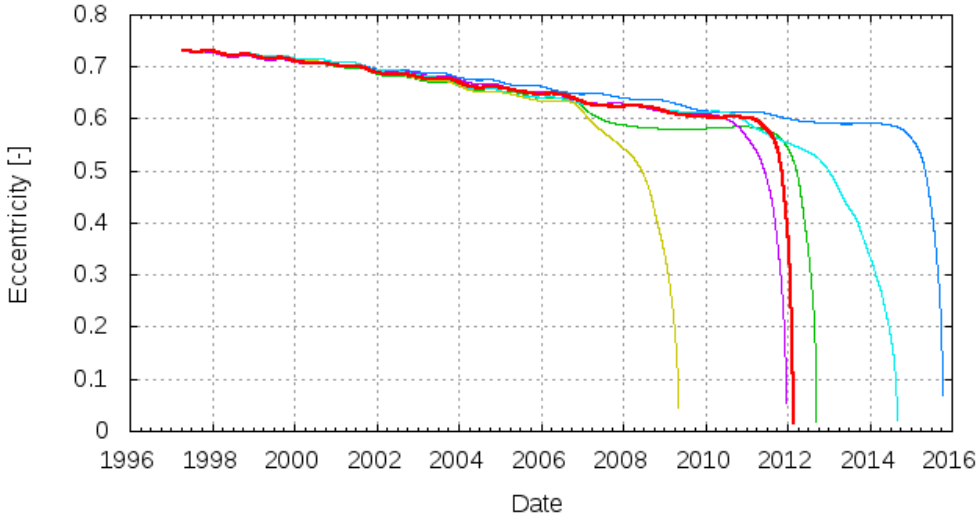
- What is the impact of the different future solar & geomagnetic activity forecast approaches on orbital decay in GTO?
- Are the predictions of OSCAR providing results in accordance with known orbits (TLE)?
- How does the orbit of an U/S in GTO evolve with time?

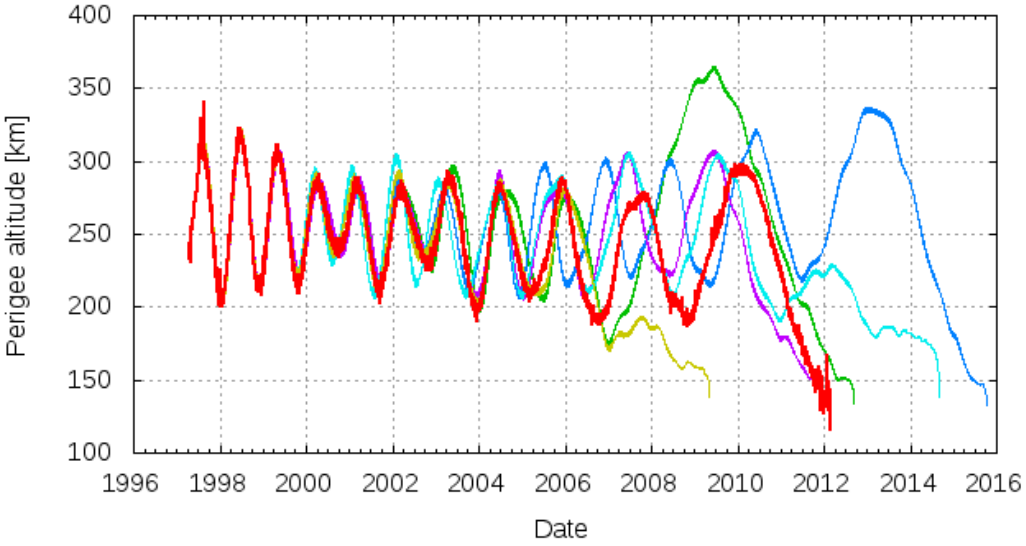
Scenario

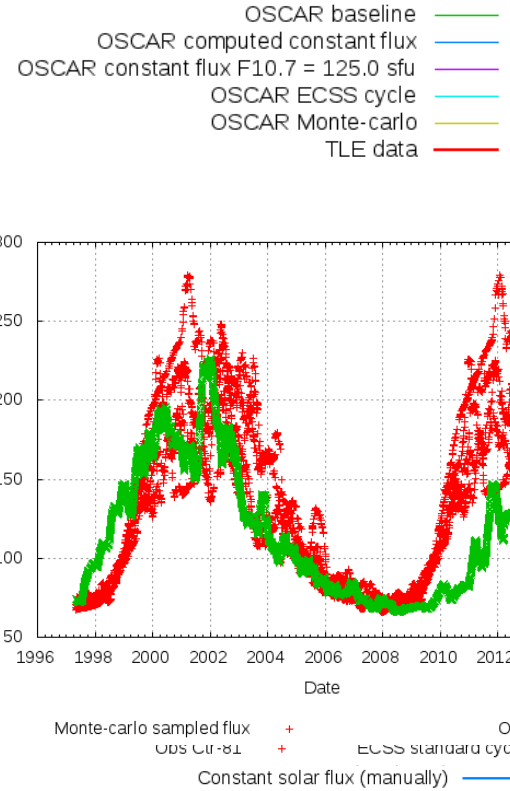
-Ariane 44LP U/S (1997-16C)
-GTO (250*36 620km)
-Cross Sectional Area 21.7 m² (11.05m*2.6m)
-Dry Mass (1 240 kg)

Data from DISCOS

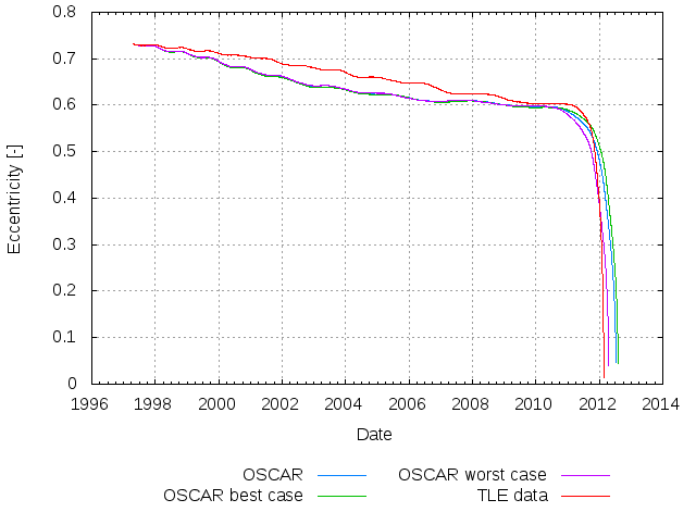
Analysis- Perigee and Semi-Major Axis

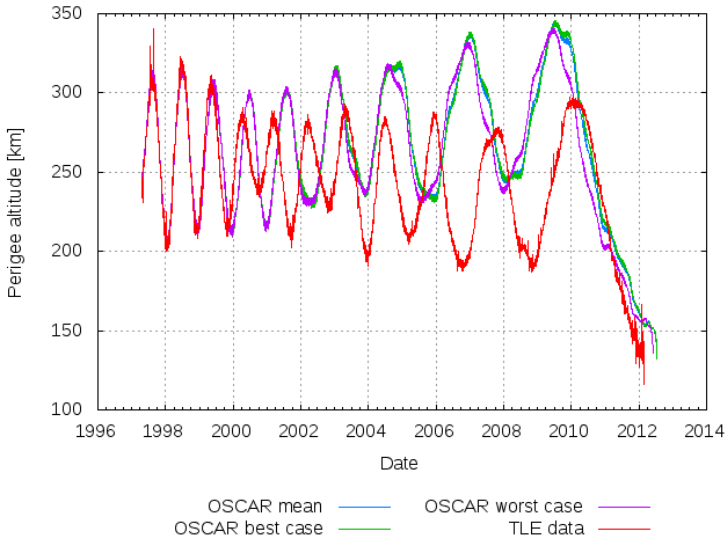




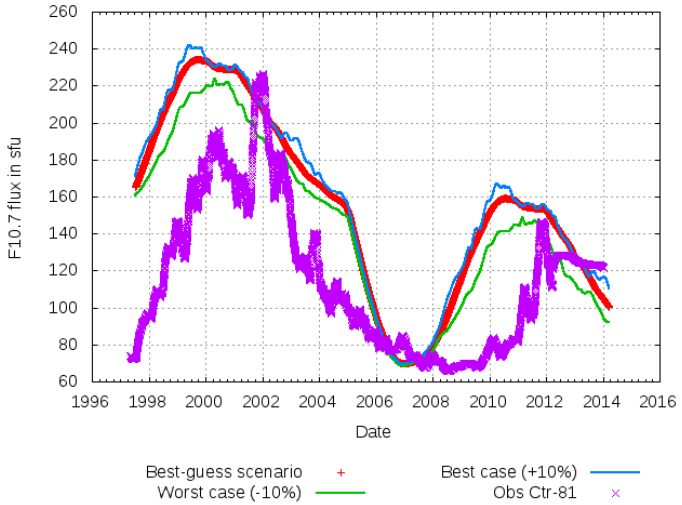


Analysis- Perigee and Semi-Major Axis



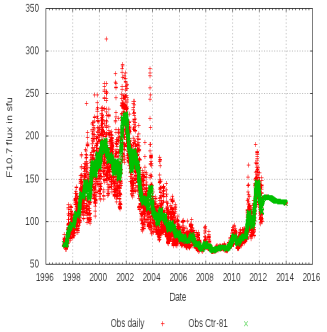


Scenario 4- Best Guess

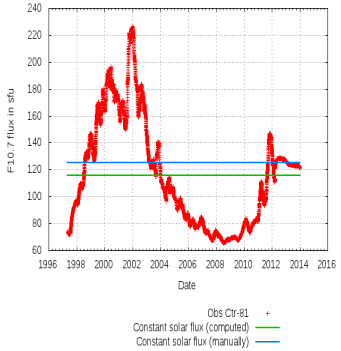


Solar Activity used for Scenario 4

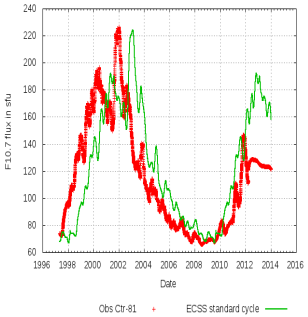
Solar Activity used for Scenario 0



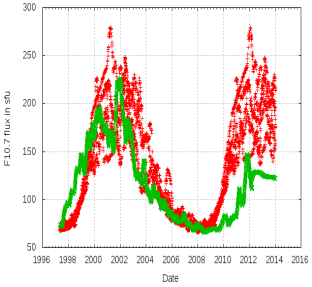
Solar Activity used for Scenario 1



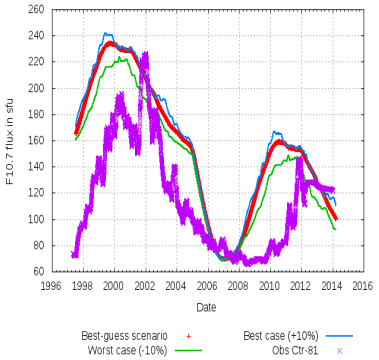
Solar Activity used for Scenario 2



Solar Activity used for Scenario 3



Solar Activity used for Scenario 4



Scenario	Solar Activity Model	Re-entry Date
Ref.	-	Begin 2012
0	Observed activity	End 2012
1	Constant equiv. Activity	End 2015
2	Sample solar cycle	End 2014
3	Monte Carlo Sampling	Begin 2009
4	Best-guess	Mid 2012

Conclusion & Next Steps

OSCAR

– High sensitivity of results wrt. the initial conditions

– Using long-term ballistic coefficient

– Different recommended methods should be used for future solar & geomagnetic activity

U/S in GTO

- Low Perigee combined with high eccentricity can lead to sun synchronious condition and affect the orbital lifetime

- Perform the same study with different objects

- Perform Monte-Carlo simulation on orbital parameters

Thanks a lot for your Attention

Special Thanks to the Space Generation Advisory Council and IAASS which supported our participation to the conference

Questions?

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Back-up Slides

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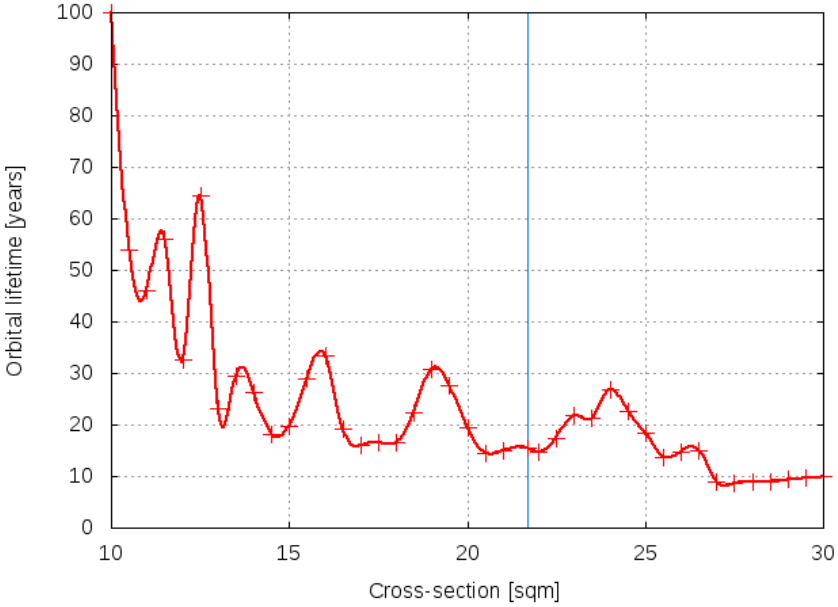
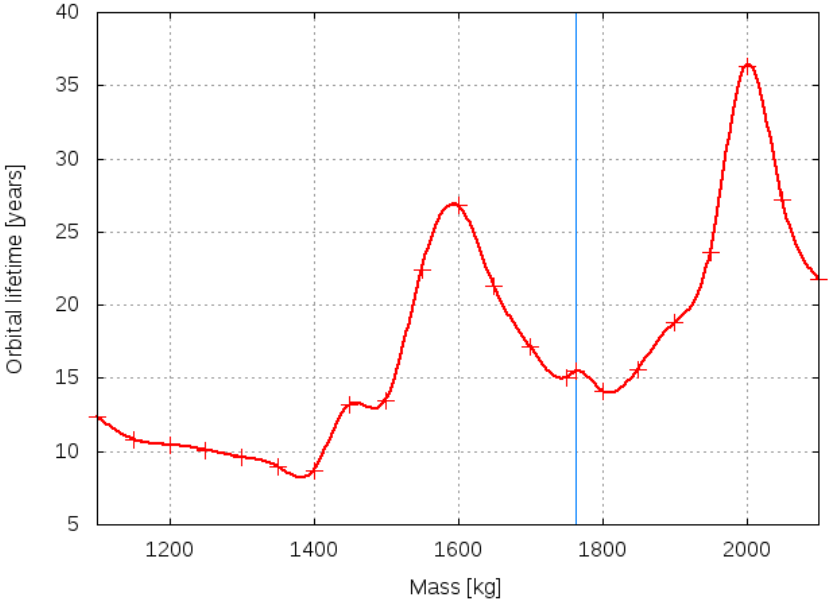
Sensitivity



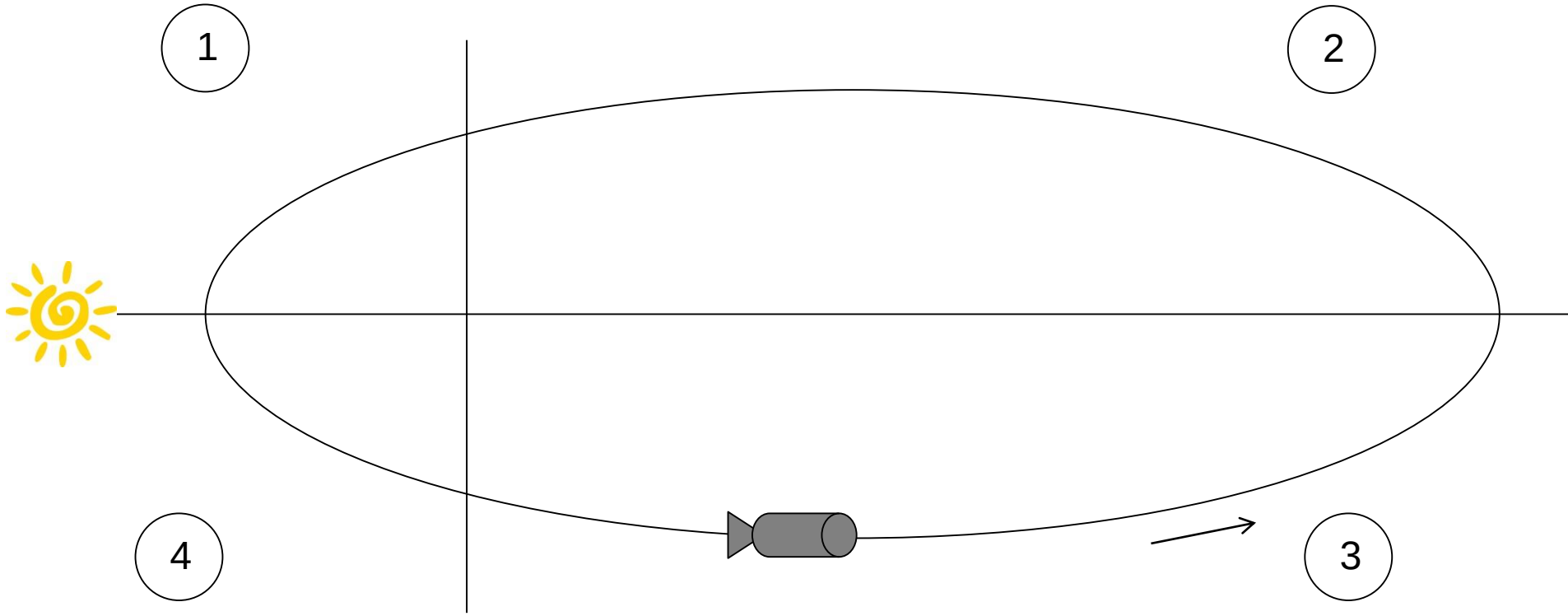


Problem- Need

- Spacecraft crossing the LEO region shall re-enter Earth‘s Atmosphere within 25 years after the end of the operational phase
- Spacecraft operating in GEO shall be disposed of in such a way that they never interfere with the GEO region

- Upper Stage represents 11% of the Space Debris Population

Third Body Effect



What is particular in GTOOrbital Pertubation in GTO

High eccentricity
Gravitational effect of the Sun and the Moon (third body effect)

Low perigee
Atmospheric Drag

Earth Geopotential
Secular Drift

$$\Delta\Omega_{day} = -9.96 \cdot \frac{\left({R_E}/{a}\right)^{7/2}}{1 - e^2} \cdot cosi$$