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** (Debris Risk Assessment and Mitigation Analysis) 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

- Oscillation
- Solar Activity used for Scenario 0
- Solar Activity used for Scenario 1
- Solar Activity used for Scenario 2
- Solar Activity used for Scenario 3

Eccentricity

Perigee altitude [km]

Date

F10.7 flux in sun

Date
Analysis - Perigee and Semi-Major Axis

Scenario 4 - Best Guess

Solar Activity used for Scenario 4
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Solar Activity Model</th>
<th>Re-entry Date</th>
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</thead>
<tbody>
<tr>
<td>Ref.</td>
<td>-</td>
<td>Begin 2012</td>
</tr>
<tr>
<td>0</td>
<td>Observed activity</td>
<td>End 2012</td>
</tr>
<tr>
<td>1</td>
<td>Constant equiv. Activity</td>
<td>End 2015</td>
</tr>
<tr>
<td>2</td>
<td>Sample solar cycle</td>
<td>End 2014</td>
</tr>
<tr>
<td>3</td>
<td>Monte Carlo Sampling</td>
<td>Begin 2009</td>
</tr>
<tr>
<td>4</td>
<td>Best-guess</td>
<td>Mid 2012</td>
</tr>
</tbody>
</table>

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
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 synchronous 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

![Graph 1: Cross-section vs. Orbital lifetime](image1)

![Graph 2: Mass vs. Orbital lifetime](image2)
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 GTO Orbital Pertubation in GTO

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

Low perigee
Atmospheric Drag

Earth Geopotential
Secular Drift

\[ \Delta \Omega_{day} = -9.96 \cdot \frac{(R_E/a)^{7/2}}{1 - e^2} \cdot \cos i \]