

A microsimulation of geostationary space debris

M. Dumont ¹ A. Petit ¹ D. Casanova ² A. Lemaitre ¹

¹naXys - UNamur

²Centro Universitario de la Defensa, Zaragoza

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Summary

- 1 Introduction
- 2 Methodology
- 3 Model of the GEO region
- 4 Creation of a synthetic population of space debris
- 5 Conclusion

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The space debris problem

Definition

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We count :

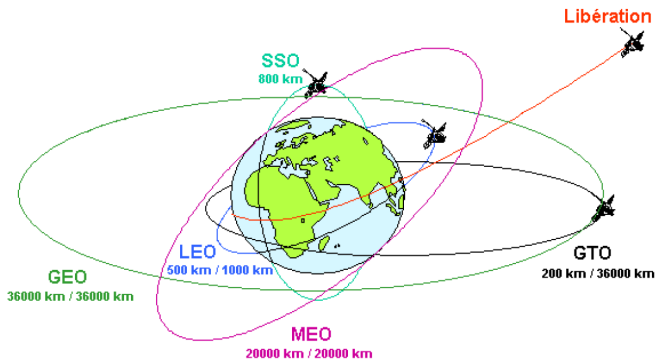
- $\approx 20,000$ space debris > 10 cm
- $\approx 500,000$ space debris > 1 cm
- \approx Several millions of space debris > 1 mm

The space debris problem

Definition

Problem : we observe only the brightest objects. A large population of space debris is unknown of us.

Type of orbit



Observation means: the USSSN network

United States Space Surveillance Network (USSSN)

A network of optical and radar telescopes is charged with the detection, trackings, cataloging and identifying of artificial objects orbiting Earth. It is composed by:

- 15 radars to observe the LEO region,
- the optical network GEODSS,
- the United Kingdom Infra-Ref Telescope as an additional instrument.

Observation means: the USSSN network

Two Line Element (TLE)

Using the observations of the USSSN network, the USSTRATCOM produces the pseudo-observations TLE each day for all objects identified, tracked, and catalogued ($\approx 20,000$). They are available online on the website www.spacetrack.org.

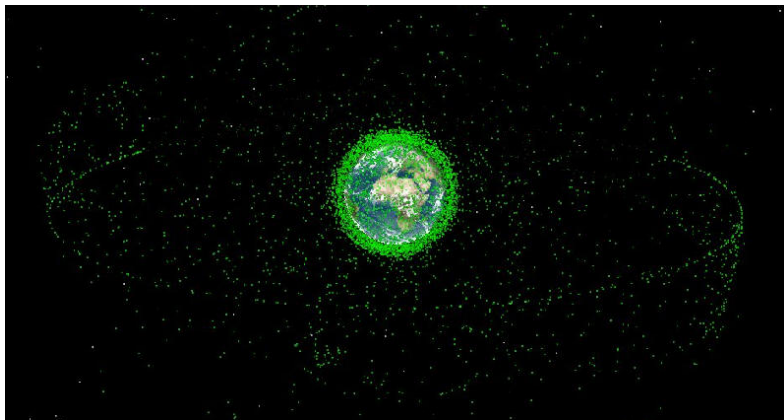
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Locate an orbit

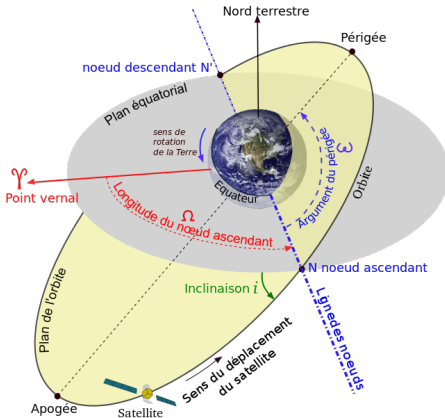
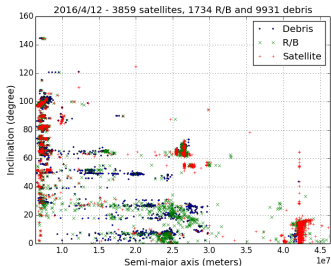
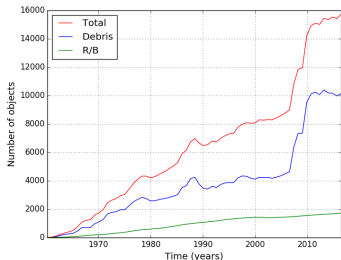


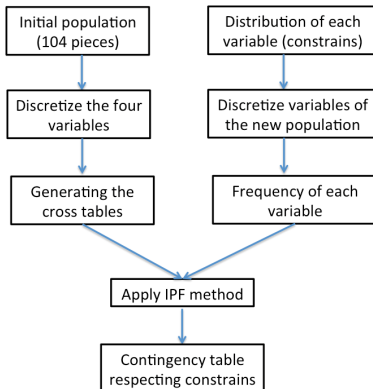
Figure: Orbital elements

The TLE catalog

- $\approx 40,000$ objects catalogued since 1957.
- $\approx 16,000$ objects currently in orbit.
- A database of $\approx 15\text{Go}$



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Deterministic model of the GEO region

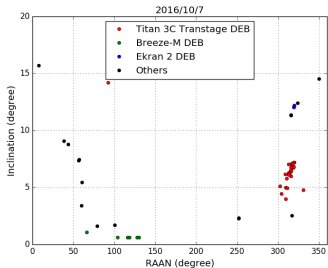
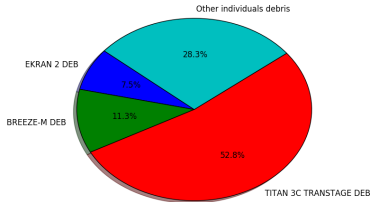


Figure: Debris catalogued in TLE catalog and in the GEO region

Deterministic model of the GEO region

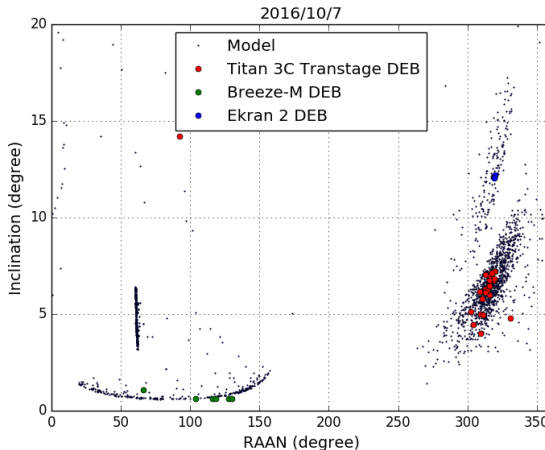
How to model the space debris population in GEO region?

We need :

- An orbit propagator called NIMASTEP that considers
 - the geopotential until order and degree five;
 - the luni-solar gravitational forces;
 - solar radiation pressure with shadowing effects;
 - atmospheric drag (below 2.000 km of altitude).
- A fragmentation model similar to the NASA breakup model.

- Take into account the orbital dynamic (resonances)
- High computational cost

Comparison of our model with the TLE catalog



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The Iterative Proportional Fitting process

What is the IPF process?

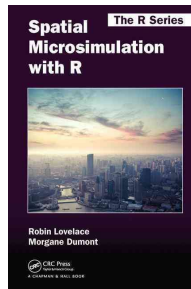
Initially: a method to create a synthetic population thanks to a sample and marginal constraints.

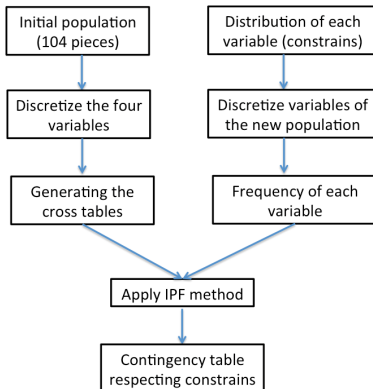
The Iterative Proportional Fitting process

What is the IPF process?

Initially: a method to create a synthetic population thanks to a sample and marginal constraints.

Interpreted as contingency tables : adapted to use it without a sample.





Initial population (simulation)

Space Debris ID	<i>sma</i>	<i>inclination</i>	<i>RAAN</i>	$\frac{Area}{Mass}$
1	1	2	1	1
2	4	1	1	1
3	1	3	3	2
⋮	⋮	⋮	⋮	⋮
<i>x</i>	1	2	4	3

The IPF process

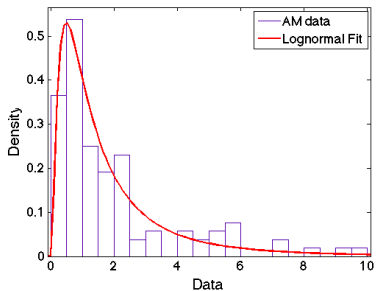
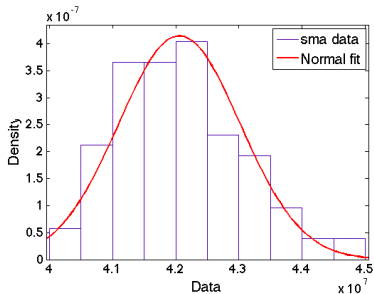
We iterate the IPF process

$$\Pi_{i,j}^t = \Pi_{i,j,k,l}^{t-1} \frac{cons_{i+}}{\Pi_{i+}^{t-1}}, \quad (1)$$

until the convergence is reached, i.e. when the distance between two contingency tables is smaller than a parameter $\epsilon = 10^{-7}$.

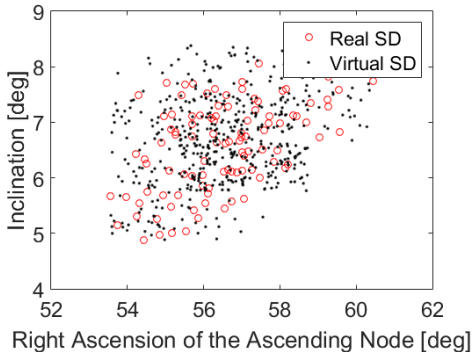
$$D(\Pi_{i,j}^t, \Pi_{i,j}^{t-1}) = \sum_{i,j} |\Pi_{i,j}^t - \Pi_{i,j}^{t-1}| \quad (2)$$

Inference of constrains



Creation of additional space debris

The IPF process create a synthetic population with 500 space debris whose statistical properties are the same that the original population.



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Conclusion

- Model of the historical fragmentations in GEO region;
- Tools to investigate the future evolution of the GEO region;
- Creation of additional synthetic debris (of all sizes if needed)
- Overcome of the computational limit of the deterministic way.

Thanks for your attention !