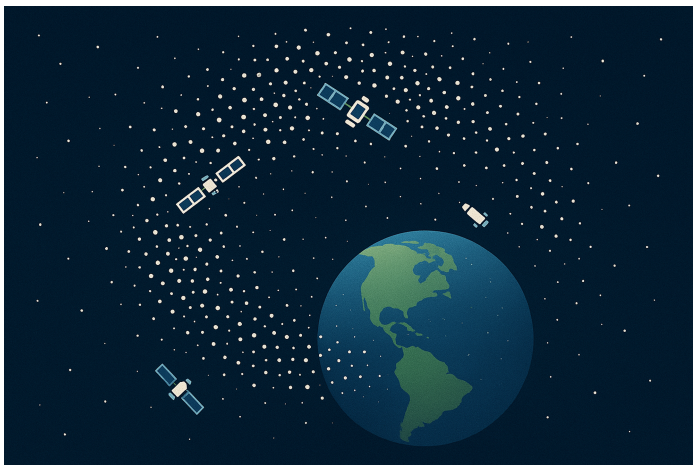
Modelling of Collisional Cascading for Space Traffic Management and Orbital Environment Sustainability

Key words : Space Situational Awareness, Space Traffic Management, Collision avoidance, Orbit Sustainability.

Department: DCAS (Department of Aerospace Vehicles Design and Control)



The recent democratization of space comes with many new challenges for space environment. The past years has seen an unprecedented number of launches and new spacecraft in orbits. This trend continues to accelerate with even larger numbers of launchers and spacecraft (incl. mega-constellations) in preparation. Space surveillance, collision avoidance and mitigation guidelines have all been put in place to curb the growth of debris in orbit and manage their associated collision risk. However, the rapid increase of debris and the telltale signs of the increasing number of impacts and near misses, threaten orbital sustainability and urges us to better understand orbital capacity and its long-term evolution [1].

Long-term sustainability may qualitatively be defined as the ability to maintain space activities into the future. The primary threat to sustainability is then the density of uncontrolled debris in orbit, which poses a collision risk to operational spacecraft. A collision with a debris generates in turn many new additional fragments, which further increase the probability of future collisions. This feedback process may conceivably trigger a collisional cascading effect that could eventually render certain orbits inoperable, the so-called Kessler syndrome [2].

Estimating accurately a single short-term probability of collision is already a computationally expensive process, requiring multiple Monte Carlo runs to produce accurate estimates. Estimating and tracking the environmental risk of cascading collisions is therefore an even more challenging problem to deal with.

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JOB DESCRIPTION:

This PhD project aims to advance methodologies for estimating the environmental risk associated with long-term evolution of clouds of fragments in orbit. The objective is to build a debris risk model with which one can assess the effect of different orbital policies (i.e., operational capacity, end of life requirements, etc) into the debris population and expected number of collisions. The objective is thus begin assessing the ultimate carrying capacity of a given orbit, before environmental damage may really put at risk spacecraft operations on this orbit.

To develop this model, the PhD candidate will likely need to develop a statistical propagation model based on point process to allow for an efficient propagation of the mean and variance statistics of clouds of debris [3]. On top of this, it is likely that surrogate propagation models can be identified for cloud propagation, which may allow to avoid recalculations of parts of the model when performing parameter exploration. Finally, ergodicity of the Earth orbit dynamical environment will be used to infer the average number of expected collisions and implement collisional cascading effects [3]. The ultimate goal is therefore to construct an efficient model (i.e., right balance between accuracy and complexity) that may be used to understand the impact of different orbital policies onto space sustainability.

REQUIRED PROFILE:

The SACLAB and DCAS (Department of Aerospace Vehicles Design and Control) are looking for a Master-level candidate with a strong background in one or more of the following topics: orbital mechanics, probability theory, multivariate statistics, and linear algebra. Proficiency in English and excellent written and verbal communication skills are also necessary. Prior research experience—such as participation in research projects, internships, or independent research work—will be highly valued.

COMPENSATION: 2569 € / YEAR
DURATION: 36 MONTHS
LOCATION: TOULOUSE

RESPONSIBLE OF THE SUBJECT:

NOM : Joan-Pau Sánchez
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APPLICATION PROCESS:

All applications should be compressed (.zip, 5MB max.) and submitted by email to Prof. Joan-Pau Sánchez **by the 18th May 2025**. Applications should contain the following documents:

- Cover letter including a statement of purpose and previous experiences
- Detailed curriculum vitae
- Course grades transcripts
- One, ideally, two recommendation letters

To avoid issues with incoming email, please include following text in the subject of the email: [PHDCASCADE].

For more information regarding this position, please contact: Prof. Joan-Pau Sánchez

REFERENCES:

[1] C. Colombo, P. Martinez, F. Letizia, B. Cattani, E. David, et al., Space capacity management and its interaction with space traffic management, Acta Astronautica, (2025).

[2] D.J. Kessler, B.G. Cour-Palais, Collision frequency of artificial satellites: The creation of a debris belt, Journal of Geophysical Research: Space Physics, 83 (1978) 2637-2646.

[3] M.-A. Carpine, Y. Paul, E. Delande, V. Ruch, Point Process Formulation of Long-Term Collision Risk Statistics from Orbital Fragmentation, Journal of Guidance, Control, and Dynamics, 47 (2024) 1309-1326.