Paper ID: 88813
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22nd IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Interactive Presentations - 22nd IAA SYMPOSIUM ON SPACE DEBRIS (IPB)

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MODELLING COLLISION RISK IN SPACE TRAFFIC FROM THE PERSPECTIVE OF THE RESIDENT SPACE OBJECTS NETWORK

Abstract

Currently, defunct satellites and debris account for the majority of the objects orbiting Earth. In recent years, the number of new satellites launched into space has boomed, and so have the frequency of conjunctions between objects and of fragmentations of abandoned spacecraft or launcher stages. This situation represents a threat for the safety of current space operations and a concern for the future sustainability of space-based services.

In this work, we use the Resident Space Objects Network (RSONet) [1] to study the state of the space resident population from a complex system perspective. Each object taken from a reference database is represented by a node in the RSONet, where links between two nodes are established whenever a conjunction between the corresponding objects is possible. The topology of the RSONet and the characteristics of each conjunction are then analysed to obtain a global picture of the system state of the orbital environment.

We develop further this approach by extending the RSONet as a two-layer network model: the first layer represents conjunctions between objects to study the possibility of direct collisions, while the second defines its links according to orbital intersections to model the possibility of indirect collisions (that is, with fragments of a debris cloud). With this strategy, we can better represent the impact of fragmentations and debris production on the rest of the population.

We use the RSONet as a framework to define an improved risk index, rooted on a previous one [1], by now explicitly considering several features for each object, e.g., the values of collision probability, the type of objects involved, their masses, the chance of explosions, etc., to classify objects and identify those contributing the most to the overall collision risk. The evolution of the risk index over periods of days to weeks is then studied and used to make predictions on the state of space traffic, on the impact of fragmentations and new launches.

[1] Romano, M., Carletti, T., Daquin, J. (2023). The Resident Space Objects Network: a complex system approach for shaping space sustainability. arXiv preprint arXiv:2310.14795.