

Line sampling procedure for extensive planetary protection analysis

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Abstract

Interplanetary missions must comply to planetary protection requirements, which set limits to the impact probability of spacecraft or launcher upper stages with celestial bodies that may support life (e.g. Mars, Europa, Enceladus). During the design of such missions, uncertainties in the design parameters of the spacecraft, random failures, errors in the determination of its state, propagation errors due to the chaotic n-body dynamics are analysed to verify that the planetary protection requirements are respected. A conventional verification using Monte Carlo (MC) method is expensive in terms of numerical resources, since the requirements also include high confidence levels of the probability estimates.

The main goal of the proposed approach is to reduce the computational load of the analysis, by employing the Line Sampling (LS) method as an alternative to the MC method for the estimation of the probability of impact between the propagated body and a celestial body. Thanks to its higher efficiency in sampling the initial uncertainty distribution resulting in fewer samples required to obtain the same confidence level, LS offers a method which can be directly used in the mission design, providing additional information about impact regions inside the uncertainty distribution, via the recognition of the time windows where close approaches with planets occur, and repeated LS applications.

The methods described above were implemented in the SNAPPshot tool suite for the verification of the compliance to planetary protection requirements originally developed at the University of Southampton in the framework of an ESA study [1] and now continued at Politecnico di Milano. They will be explained and used together to analyse different interplanetary missions as test cases, such as the ESA/NASA Mars Sample Return mission, and the ESA mission JUICE for the Jovian moons.

References

- [1] Letizia F., Colombo C., Van den Eynde J., Armellin R., Jehn R., SNAPPSHOT: *Suite for the numerical analysis of planetary protection*, 6th International Conference on Astrodynamics Tools and Techniques (ICATT), 14-17 Mar. 2016, Darmstadt.

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