Paper ID: 48051
oral
student

IAF SPACE EXPLORATION SYMPOSIUM (A3)
Solar System Exploration (5)

Author: Mr. Matteo Romano
Politecnico di Milano, Italy, matteo1.romano@polimi.it

Dr. Camilla Colombo
Politecnico di Milano, Italy, camilla.colombo@polimi.it
Mr. Jose Manuel Sánchez Pérez
ESOC - European Space Agency, Germany, jose.manuel.sanchez.perez@esa.int

EFFICIENT PLANETARY PROTECTION ANALYSIS FOR INTERPLANETARY MISSIONS

Abstract

Planetary protection requirements set important constraints on the design of interplanetary trajectories, since they aim to avoid the contamination of planets and moons where life could have developed, by limiting the probability of impact between spacecraft or launcher stages and these celestial bodies. The process of verifying that interplanetary missions respect the requirements must take into account uncertainties in the design parameters of the spacecraft, random failures, errors in the determination of its state, chaotic n-body dynamics which introduces numerical errors in the propagation of the trajectory. This is expensive in terms of numerical resources, since the requirements also include high confidence levels of the probability estimates.

Newly developed methods are used to decrease the computational load of the analysis. On one side, as an alternative to the conventional Monte Carlo method, which propagates a large number of initial conditions directly sampled from an uncertainty distribution, the impact probability is estimated by using techniques (such as line sampling and its derivates) that sample the initial distribution in a more efficient way, aimed to provide a probability estimation with a higher confidence level, or employing a lower number of samples to reach the desired accuracy level; the uncertainty distribution is also represented in such a way the sampling process is simplified. On the other side, the orbital propagations are carried out with methods defined to enhance the accuracy of the numerical integration, both in terms of long-term propagation in the n-body dynamics, and in terms of characterisation of the close approaches with planetary bodies; from this point of view, alternative parametrisations and regularisations of the dynamics are explored to address the problem of errors induced by multiple fly-bys.

The methods described above will be explained and used together to analyse different interplanetary missions as test cases. Attention will be given to the analysis of the ESA mission JUICE for the Jovian moons, as its planetary protection analysis presents challenges due to the possibility of frequent close approaches with the moons and the permanence in an environment characterised by strong radiation levels.