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Efficient design of low lunar orbits based on Kaula recursions

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Preliminary design of artificial satellite missions commonly relays on the use of simplified models that comprise the bulk of the dynamics. In the case of the gravitational potential, the amplitude of long-term oscillations of the orbital parameters is roughly one order of magnitude larger than the short-period oscillations. Because of that, dealing with just the few more relevant zonal harmonics of the potential is generally suitable for the initial steps of the procedure. In addition, the long-term evolution of the orbital parameters is customarily investigated through averaging procedures that remove the higher frequencies of the motion, in this way notably speeding the process of mission design.

However, there are cases in which the use of simplified models is not an option and full zonal potential models must be used instead. The paradigm is provided by the moon, where, due to the irregular character of the moon gravity field, mission designing of low altitude lunar orbits needs to deal with tens of, contrary to just a few, zonal harmonics. The analytical approach is still possible, but the requirement of handling huge expressions formally usually discourages mission planners, who then resort to numerical procedures. Still, useful compact recursions for dealing analytically with the problem exist in the literature since many years ago, yet limited to the equations of the averaged flow.

On the other hand, the correct computation of initial conditions requires the mathematical transformation from mean to osculating elements, and vice-versa, which may be crucial for the design of missions dealing with unstable orbital configurations, which is the common case of science orbits under third-body perturbations. Based on Kaula's popular recursions, we derive new formulas for the efficient mean to osculating transformation. While some efforts in providing these transformation equations have been made by different authors in the past, we show that the performance of the new formulas clearly surpass existing proposals in the literature. The new Kaula-type recursions, together with Kaula's original recursions for the averaged zonal potential, provide a compact and efficient way of handling analytical solutions of full potential models. The use of this kind of solution is illustrated with application to the design of low lunar orbits.

Summary

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