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ANALYSIS OF PROPER ORBITAL ELEMENT FOR RESIDENT SPACE OBJECTS

Abstract

One of the major challenges of space situational awareness (SSA) is predicting with sufficient accuracy the location of all significant resident space objects (RSOs) at any future time, a problem that has been compounded in recent years with the launch of numerous small satellites by many nations, the growth of an international military presence in orbit, and the proliferation of orbital debris. Developing and maintaining the space object catalog in this modern era will require significant improvements in our understanding of the way objects behave in circumterrestrial space over both orbital, decadal, and even centennial timescales. As near-Earth space gets more and more congested, the need for a classification scheme based upon scientific taxonomy is needed to properly identify, group, and discriminate RSOs. While osculating and mean orbital elements change in quasi-periodic and in principle predictable manners due to perturbations, proper elements are quasi integrals of motion of an object in space that remain practically unchanged over very long timescales. These celestial fingerprints, used extensively in asteroid dynamics, have only recently been explored in the circumterrestrial context and appear to offer unique and interesting solutions to a number of challenges in SSA, including the detection of maneuvers. In this paper, we will present and compare various theories for the computation of RSO proper orbital elements. Presently, the method of choice to compute more accurate, in the sense of stable, unchanging, proper elements is to integrate the equations of orbital dynamics, and extract constants of motion directly from a numerical frequency analysis of the predicted evolution. We have developed an extensive set of computational tools for the exploration and simulation of the long-term orbital dynamics about Earth, accounting for gravitational and non-gravitational perturbations. We will adapt these capabilities to the computation of RSO proper elements and investigate how orbit uncertainties manifest in these dynamical invariants.