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ANALYSIS OF THE SUITABILITY OF ANALYTICAL, SEMI-ANALYTICAL, AND NUMERICAL APPROACHES FOR IMPORTANT ORBIT DYNAMICS TASKS

Abstract

Astrodynamics tools must be suitable for the tasks to which they are applied. Physical hypotheses analytical representations of relevant phenomena, distribution of underlying observations, accuracy and precision of input data, numerical implementation, and computational architecture MUST be self-consistent. Practitioners often overlook this fundamental principle. This leads to spurious outcomes, numerical artifacts, and masking important physical consequences. There are many examples. Recent research by Numerica, Inc. (Jeff Aristoff) illuminates one aspect of the problem, fixed time increments in propagating trajectories. The governing equations are generally "stiff." The time scales of some phenomena, such as communication transactions occur on time scales orders of magnitude shorter than most kinetic phenomena. One cannot always assume that long time scale phenomena are "frozen" when more rapid events transpire. For example, there are always discontinuities at some level from one time step to the next, whether in depend variables or derivatives at some order. These matter for communications, since numerically induced Doppler shifts may erroneously force transmissions out of receiver bands, resulting in loss of lock which must be restored. Other such diverse phenomena include continuous low thrust, which is best not represented by sequences of impulses for reasons similar to the Doppler shift issue. GNC can also be affected by the manner in which orbits are propagated. Thorne recently reported that the precision inherent in a numerical implementation can be the difference between convergence and divergence. It is also dangerous to propagate numerically over time spans very long compared to step sizes. Furthermore, increasing step size may deprecate important phenomena on shorter time scales. This paper will demonstrate several such dilemmas and judge the suitability of analytical, semi-analytical, and numerical approaches to different classes of problems. Given the vulnerability of numerical approaches to numerical instabilities and accumulating round off error and the imprecision of all purely analytical theories, we will demonstrate that semi-analytic theories are most suitable for a wide variety of tasks. It is important to recognize that no single approach is suitable ubiquitously and that choosing the most appropriate approach requires insight and experience.