MAE Seminar Series

Development of the Semi-analytical Satellite Theory and Applications

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Abstract

The semi-analytical theory for the motion of a space object replaces the conventional equations of motion with two formulas: 1) Equations of motion for the mean elements, and 2) Expressions for the short periodic motion. These two expressions are derived from the assumption of two asymptotic expansions that are used to transform the conventional equations of motion. The lower frequency of the mean element equations of motion allows for much larger integration steps than are usually employed with the conventional equations of motion. The expressions for the short-periodic motion allow for the recovery of the precise perturbed motion. The coefficients in the formulas for the short-periodic motion are also slowly varying. The orbital elements employed in this development are nonsingular, thus avoiding the small eccentricity and small inclination singularities. The semi-analytical satellite includes comprehensive force models. These force models involve spherical harmonic expansions and recursive functions. The force models are taken through the transformation to the mean element space. The special functions and the recursive formulation in mean element space are discussed. The mean elements are very useful solve-for parameters in orbit estimation processes: both weighted least squares and Kalman Filter processes have been constructed. The performance of the Semi-analytical Satellite Theory for Molnya orbits and Topex orbits is discussed. The development of a standalone version of the semi-analytical propagator (separate from the complete orbit determination system) is discussed. The semi-analytical theory is compared with the NORAD Two Line Element (TLE) general perturbation orbit propagator and an approach for enhancing the accuracy of the TLE by the addition of a portion the semi-analytical theory periodic model is demonstrated. A constellation design capability based on parallel computing, nonlinear optimization, and semi-analytical theory is discussed. Previous graduate student research in this area is reviewed. Future work is outlined.

Speaker Biography

Dr. Paul Cefola received his Ph.D. in Mechanical Engineering (Dynamics and Controls) from Rensselaer Polytechnic Institute (RPI) in 1969. His employment includes: TRW Systems Group (now Northrop Grumman Corp), 1969–1971; Computer Sciences Corporation, 1971–1975; Draper Laboratory, 1975–2001; MIT Lincoln Laboratory, 2001–2004; and Consultant, 2004 to present – Aerospace Systems, Spaceflight Mechanics, & Astrodynamics. From 1980 to 2008 he served as an Adjunct Faculty in the Aeronautics & Astronautics Dept at MIT where he supervised nearly 35 graduate theses. He has won numerous awards including: the American Astronautical Society (AAS) Brouwer Award, AAS Fellow and American Association for Advancement of Science (AAAS) International Scientific Cooperation Award. Dr. Cefola has approximately 100 publications and conference papers.

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