Semianalytical Propagation Of Satellite Orbits About An Arbitrary Central Body

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Precision mean element (PME) satellite theories play a key role in orbit dynamics analyses. These theories employ:

- nonsingular orbital elements
- comprehensive force models
- Generalized Method of Averaging
- Numerical interpolation concepts

The Draper Semianalytical Satellite Theory (DSST) (Refs. 1 - 6), whose development was led by the author, and the independently-developed Universal Semianalytical Method (USM) (Ref. 7) are examples of such theories. These theories provide the capability to tailor the force modeling to meet the desired computational speed vs. accuracy trade-off. The flexibility of such theories is demonstrated by their ability to include complicated atmosphere density models and spacecraft models in the perturbation theory context. The value of high speed satellite theories, in this era of computational plenty, is that they allow new ways of looking at astrodynamical problems such as orbit design (Refs. 8, 9) and atmosphere density updating (Refs. 10, 11).

In the mid to late-1980's, the geodynamics community led the development of very precise geopotential models such as GEM T2 and GEM T3 (Ref. 12), and with the subsequent analysis of the TOPEX flight data, JGM-2 and JGM-3 (Ref. 13). These were high degree and order geopotentials, at least 50 x 50. In 1993, the DSST implementation in the GTDS program was extended to include the 50 x 50 geopotential models (Ref. 14). The 50 x 50 geopotential, J2000 integration coordinate system, and solid Earth tide capabilities were integrated in GTDS by Scott Carter (Ref. 15). This capability demonstrated 1 m accuracy versus the TOPEX Precise Orbit Ephemerides. Subsequently the DSST Standalone program was also extended to include high degree and order geopotential models (Ref. 5). More recently GTDS has been hosted in the Linux PC environment. However, all of these efforts have been limited to modeling the motion of an artificial Earth satellite. They did not consider the additional complexities associated with lunar, planetary, or other natural satellite orbiters. Such complexities include:

- additional coordinate systems (associated with the direction of the north pole of rotation and the prime meridian of the new central bodies) (Ref. 16)
- normalized gravity model coefficients (desirable for high degree and order fields) (Ref. 17)
- indirect oblateness

- generation of large degree and order spherical harmonics (necessitated by the mass distributions of the central bodies) (Ref. 18)
- different central body rotation rates and their impact on the partitioning of short periodic and mean element perturbations (Ref. 19)
- complications introduced because the J_2 harmonic is no longer dominant as it is for the Earth spherical harmonic field
- different atmosphere density models

The production of high degree and order gravity models for central bodies other than the Earth is now a reality. Consider the 165 x 165 model for the lunar gravity field (Ref. 20), the 80 x 80 model for the Mars gravity field (Ref. 21), and the 180 x 180 model for the Venus gravity field (Ref. 22). The existence of these high degree and order fields for central bodies other than the Earth motivates the extension of the DSST to deal with arbitrary central bodies.

The emphasis in this paper is on orbits with the Moon and Mars as the central body. The results include modifications to the DSST algorithms and initial numerical results.

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