Improve the Tesseral Linear Combination Short-Period Motion Model in the DSST propagator

The Draper Semi-Analytical Satellite Theory (DSST) is a very high performance propagation model. It performs propagation by using numerical integration for the mean elements, using very large step sizes to achieve high speed and by using analytical models for short period terms. It is well suited for a large number of applications, from operations and station-keeping to long term analysis and end of life estimation.

The Orekit implementation of this model includes the traditional force models (zonal and tesseral terms in the geopotential, radiation pressure, atmospheric drag, Sun and Moon third body attraction). All of these models contribute to both the mean element and short period motions.

For the tesseral terms, there are three models: (1) the tesseral resonance (included in the mean element rates), (2) the tesseral m-daily contributions to the short-period motion, and (3) the tesseral linear combination terms (also a short-period motion). Both the tesseral resonance and the tesseral linear combination terms require a general form of the Hansen coefficients (an eccentricity function) and derivatives of the Hansen coefficients. The Hansen coefficients and the derivatives are computed via recursions. The recursions are initialized via the Newcomb operators. Modified forms for the Hansen coefficients and the Newcomb operators were developed for the DSST to maintain good performance for high eccentricity cases.

“Shallow resonance” cases occur with orbits that have long period repeat ground tracks. Such long repeat ground tracks are frequent in the orbits designed for earth observation. In these cases, the important tesseral linear combination terms are: (1) low degree and order terms in the geopotential, and (2) high degree and order terms centered around the shallow resonance order.

The current DSST algorithm, to model high order shallow resonant terms together with their side bands, requires computation of many negligible intermediate terms in order to include the high degree and order terms. This impacts the efficiency of the DSST. In this task, we want to develop an architecture for the tesseral linear combination terms that allows separate, selectable, regions for the short-periodic tesseral terms: one region for low degree and order terms and another region(s) for shallow resonance side band terms.

In a subsequent phase, we would like to add a model for the J2/shallow resonance second order coupling terms.

In the current task, we would also like to revisit the partitioning of the Hansen coefficient/Newcomb operator computations between the Newcomb operator database and the DSST orbit propagator. The current architecture is based on the data memory available to orbit propagation application programs in the early 1980s. This effort may involve research into recent work on (1) the Hansen coefficients and (2) rational function approximation.

Note that this is a difficult subject.

Two mentors will follow this project.