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VALIDATION OF DSST C/C++ AGAINST ORIGINAL FORTRAN VERSIONS: MEAN ELEMENT AND SHORT-PERIOD MOTION MODELS, PARTIAL DERIVATIVES

Abstract

The Draper Semi-Analytical Satellite Theory (DSST) is a high-precision orbit propagator based on the mean equinoctial elements with comprehensive force modeling. The DSST is based on the Method of Averaging and includes partial derivatives of the perturbed motion. The DSST supports both Batch Least Squares and Recursive Filter orbit determination.

Both Lagrange and Gauss forms of the VOP equations are employed. The Lagrange form is used for the conservative terms: geopotential, lunar-solar point masses, and the solid Earth tides. The detailed models emphasize recursions with mean elements as the arguments. The Gauss form is used for the atmosphere drag and solar radiation pressure; the integrals are evaluated by numerical quadrature. This facilitates complex atmosphere densities and spacecraft models in the DSST.

The short-periodic models are developed as a Fourier series in a rapidly varying phase angle. The Fourier coefficients in these series are functions of the slowly varying mean equinoctial elements. The tesseral terms employ Jacobi polynomials and Hansen coefficients. Fast computation is achieved because numerical integration can be done with large steps and the short-period terms are closed-form evaluations. The coefficients in the short-periodic expansions are slowly varying and can be interpolated on a large grid.

The DSST exists both in the Goddard Trajectory Determination System (GTDS) and as a Standalone program. The Standalone employs an innovative file-driven architecture. Recently, the Fortran-77 DSST Standalone code has been migrated to C/C++ at the University of La Rioja.

In this work, we discuss the validation and verification of the mean-element and short-period motion models and the partial derivatives of perturbed motion in the C/C++ version. We provide comparisons of C/C++ DSST against both the F77 DSST Standalone and against the GTDS DSST. We introduce new capabilities into the DSST Standalone to access the 196-year GTDS Timing Coefficient and SLP ephemeris files. Automated procedures support multiple comparison cases for C/C++ DSST vs F77 Standalone and for DSST Standalone vs GTDS. We consider a grid of values for semi-major axis, a, eccentricity, e, and inclination, i, for different orbit types. We conduct an exploratory data analysis using the box-and-whisker approach. We identify outlier cases for detailed study. We execute a sequence of test cases with increasing complexity in the interpolator coefficient management and the short-period coefficient models. We found total agreement between the DSST versions. The DSST will be an important tool for maintaining the space debris catalog and for controlling satellite mega-constellations.