VALIDATING SHORT PERIODICS CONTRIBUTIONS IN A DRAPER SEMI-ANALYTICAL SATELLITE THEORY IMPLEMENTATION: THE OREKIT EXAMPLE

Nicolas Bernard(1), Luc Maisonobe(1), Lucian Barbulescu(2), Petre Bazavan(2), Sorin Scortan(2), Paul J. Cefola(3), Massimo Casasco(4), Klaus Merz(5)

(1) CS Systèmes d'Information, 5, rue Brindejonc des Moulinais, 31506 Toulouse Cedex 5, France, +33-5-61-17-66-66, nicolas.bernard@c-s.fr, luc.maisonobe@c-s.fr
(2) CS Romania, Str. Pacii, no. 29, Craiova, Romania, lucian.barbulescu@c-s.ro, petre.bazavan@c-s.ro, sorin.scortan@c-s.ro
(3) Univ. at Buffalo, State University of New York, Amherst, NY, USA, paulcefo@buffalo.edu
(4) ESA/ESTEC, Keplerlaan 1, 2201 AZ Noordwijk, The Netherlands, Massimo.Casasco@esa.int
(5) ESA/ESOC, Robert-Bosch-Str. 5; 64293 Darmstadt, Germany, Klaus.Merz@esa.int

ABSTRACT

Amongst existing orbital propagation techniques, semi-analytical methods are of great interest: by separating computations of the long-term evolution from one side, and the short-term variations from the other side, they tend to be significantly faster than classical numerical methods while keeping similar accuracy.
The Draper Semi-Analytical Satellite Theory (DSST), developed by Paul Cefola and his colleagues, is one of them. The DSST has the advantage to cover an extensive range of perturbations: central-body potential contribution, with zonal harmonics and gravitational tesserals, third-body potential contribution, and non-conservative contributions, such as solar radiation pressure and atmospheric drag. Furthermore, it benefits from an excellent maturity, coming from decades of research and development. Unfortunately the DSST, as many other semi-analytical techniques, was for long unavailable for the wider Astrodynamics community.
Aiming to fill this gap, the Orekit open-source library contains in its last release a complete and operational implementation of the DSST.

This paper focuses on the validation process of this implementation, and discusses in particular the validation of the short-periodics contributions. In Semi-Analytical Satellite Theory, these contributions are represented and computed through Fourier series. In order to achieve this validation process, two distinct references were used. First one is the Fortran 77 DSST Standalone Orbit Propagator, developed under the lead of Paul Cefola. Second one is a classical numerical propagator.
First key topic of this process was the validation of short-term variations due to central-body. Indeed, irregularities in the Earth potential, and especially the Earth oblateness (J2), are the main contributors to short-periodic variations. Then, the third body contribution had been studied, followed by the contributions of the non-conservative forces, that is to say atmospheric drag and solar radiation pressure. The last key topic was the conversions between mean and osculating equinoctial elements, with tests covering both mean-to-osculating and osculating-to-mean elements conversions.

Validation was lead on a large panel of orbits, ranging from Low-Earth Orbits to High-Earth Orbits. Amongst these orbits, one can find most commonly used orbits, such as Earth observation LEOs, MEO corresponding to global navigation satellite systems (GPS, Galileo orbits), and GEOs used for telecommunication satellites. One can also find more exotic orbits, having for instance a high eccentricity or a very high apogee altitude.

Comparison with legacy Fortran 77 software demonstrated a great consistency. The outputs produced by these two different implementations of the DSST theory are almost identical, yielding very small numerical differences on the evolution of the osculating elements. This allowed validating the short-periodic contributions of zonal and tesseral geopotential and third body potential.

Comparison with a numerical propagator demonstrated also a very good consistency, allowing validating the short-periodic contributions of drag and solar radiation pressure (as they were not implemented in Fortran reference software). However, the numerical differences measured are in this comparison slightly higher than with the first reference. This can be explained by the fact that Orekit DSST implementation lacks for now of second order contributions having a significant impact on the orbit evolution, in particular J2-J2 and J2-Drag contributions.

This study and the development of the Java implementation were performed under contract with the European Space Agency.