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ON-BOARD ORBITAL PROPAGATION OF NANOSATELLITES USING NORAD TLE, SGP4, AND GPS

Abstract

Paramount to any satellite mission is the acquisition of accurate position and velocity information at any particular point in time. With several satellite tracking and propagation methods available, the use of the Two-Line Element (TLE) supplied by the North American Aerospace Defense Command (NORAD) in conjunction with the Simplified General Perturbations Satellite Orbit Model 4 (SGP4) is considered the most popular choice for nanosatellite-scaled missions. If a particular mission requires greater accuracy then can be achieved by the SGP4 model, an on-board GPS receiver is often a natural choice. This paper describes a technique for high precision orbital propagation through the use of a GPS receiver for initial orbital information, complimented with NORAD TLE at the same epoch, using the SGP4 model. The goal is to demonstrate near-GPS level orbital determination through SGP4 propagation with an effort to reduce the duty cycle required by an on-orbit GPS receiver. This propagation technique is primarily geared towards nanosatellite scaled missions with regards to stringent power and antenna pointing requirements.

The motivation to investigate alternatives to relying solely on resources provided by NORAD arise from the fact that there are errors associated with the TLE – namely, the initial error of the TLE itself– as well as intrinsic error propagation of the SGP4 model. Unfortunately, there is no error covariance estimate associated with TLEs; however, a number of papers have attempted to quantify the intrinsic error associated with the NORAD SGP4 propagator and TLE error. In *Kelso, T.S. (2007)*, SGP4 is compared with GPS precision ephemerides. The results show error accumulation of up to 50km in along track range error after a period of 15 days. The initial range error associated with NORAD TLE is commonly assumed to be up to approximately 20km (*Moraes, R.V. et. al., 2002*). This value is unacceptable for certain missions.

Similar work has been pursued in *Cho et. Al. (2002), Lee (2002)* and *Ernandes (1994)* in which the motivation was driven primarily by the irregular periodicity of NORAD TLE generation. In particular, *Cho et al. (2002)* developed a method based on a least-squares approach to estimate the mean orbital elements suitable for NORAD TLE based on osculating orbital elements. Said method also includes a process of determining the B* term, however it requires 3 days of prior observations. Therefore this technique does not depend on NORAD for tracking, merely the SGP4 propagator and osculating orbital elements (which could potentially be obtained from a GPS receiver). Results show this method to be valid within certain periods of time before the errors accumulate beyond reasonable limits. By contrast, the technique described in this paper uses a simpler, more succinct method of orbital propagation which does not require additional computation, as is the case with previous work.

This technique can be used for ground station tracking and/or on-board orbital propagation on any Earth-orbiting spacecraft mission with a GPS receiver, regardless of the receiver's original purpose. The Space Flight Laboratory (SFL) at the University of Toronto Institute for Aerospace Studies (UTIAS) has developed the Canadian Advanced Nanospace eXperiment 2 (CanX-2) nanosatellite that was launched in April 2008 on board the PSLV-9 launch vehicle from Sriharikota, India. This satellite is currently performing a GPS occultation experiment of the Earth's atmosphere using an on-board GPS receiver. GPS data from this satellite has been used to confirm the soundness of the technique described in this

paper. Results of this technique are also plotted against a numerical method, namely, Satellite Tool Kit's (STK) High Precision Orbital Propagator (HPOP) for redundant validity.