Covariance Propagation For Earth Satellites

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Many users of the ephemerides provided by US Space Command want an estimate of the accuracy of the orbit prediction using the ephemerides. This accuracy estimate is typically provided by the covariance. The accuracy of the covariance is affected by sensor error modeling, dynamic error modeling and the method propagation of the covariance. Numerical integration of the covariance with the full dynamic force model is the most accurate, but the most computationally expensive. An accurate analytical propagation would save considerable computation time, particularly when one is primarily interested in just determining the estimated error. In this paper we will address the propagation of the covariance and the effect of neglecting the nonlinear effects in the propagation. Two cases will be considered: a) a low Earth orbit satellite with the standard radar observations, and b) a near geosynchronous satellite with optical observations. A comparison of three propagation methods will be performed: a) Numerical integration of the Lyapunov equation in ECI coordinates, b) Analytical propagation in a rotating reference frame fixed to the nominal satellite position (Hill's equations) with a recently developed state transition matrix for elliptic orbits and mean $J2$ effects. A recently developed nonlinearity index for measuring the effect of neglected nonlinearities will be used.