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LOW-EARTH ORBIT PREDICTION ACCURACY REVIEW OF MODERN EMPIRICAL ATMOSPHERIC MODELS AND SPACE WEATHER DATA SOURCES

Abstract

As the catalog of space objects in low-Earth orbit (LEO) grows and we witness an increasing number of conjunction events, owner/operators find themselves in need of generating accurate orbit predictions to share with the space community for the purposes of space situational awareness.

In this paper, we evaluate the prediction accuracy of three different modern empirical atmospheric models—NRLMSISE-00, NRLMSIS 2.0, and JB2008—using two sources of space weather data—daily predictions retrieved from the NOAA Space Weather Prediction Center and 3-hourly predictions from Space Environment Technologies (known as JBHSGI indices).

For this study, we have selected two satellites that operate in different orbit regimes: NASA's Global Precipitation Measurement (GPM) satellite, which is in a 400×390 km, 65° orbit, as well as PlanetIQ's low mass (40 kg) GNOMES-3 spacecraft that is flying in a Sun-synchronous orbit at 650 km altitude.

To evaluate the performance of each atmospheric input, we cannot simply compare generated ephemerides with the same initial conditions and different atmosphere models; parameters such as the drag coefficient must also be estimated with the same model before generating new predictions. Thus, we have set up an end-to-end flight dynamics system where we process new GNSS NavSOL tracking data for each satellite multiple times per day through SpaceNav's in-house orbit determination (OD) service to generate definitive ephemerides. With the final state vector and estimated spacecraft parameters, we then generate a new 7-day predictive ephemeris using the same model from the OD process. In both cases, the state propagation is handled by our in-house software, which includes support for the NRLMSISE-00, NRLMSIS 2.0, and JB2008 atmospheric models, and always uses the most recent space weather data from the selected source.

By aggregating the results over several months and overlapping predicted ephemerides on top of the previously generated definitives, we can determine which model produces statistically the best results. For each atmosphere model and each date and time over the span of the study, we have a definitive state (position and velocity with covariance) and multiple predicted states (the latest result, as well as the predicts from 1–7 days before). This large dataset allows us to compare the position and velocity differences in the RIC frame for each model at different prediction lengths. Additionally, we can evaluate that the definitive ephemerides obtained by each model are self-consistent (within the uncertainty of each other) and that consecutive predicted ephemerides for a given model are also self-consistent.