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ORBITAL DECAY PREDICTION FOR LOW EARTH ORBIT SATELLITES USING A SINGLE TWO LINE ELEMENT

Abstract

This study proposes a methodology for predicting the long-term orbital decay of low earth orbit (LEO) satellites using a single two-line element (TLE). State vectors are propagated by Simplified General Perturbation 4 (SGP4), subsequently converted into new TLE data via nonlinear system solutions. The atmospheric density is calculated using the NRLMSISE-00 atmospheric model, while the ballistic coefficient (BC) is optimized through the computation of the median of the B* parameter derived from the target satellite's TLE dataset. The proposed method demonstrates a reduction in cumulative propagation errors, resulting in improved orbital decay prediction. This advancement holds considerable promise for enhancing satellite mission planning and space debris mitigation strategies.
Keywords : LEO orbital decay, SGP4, Time series analysis

Introduction

Since 2020, LEO satellites have experienced unexpected orbital decay by increased atmospheric drag due to high solar activity. The original SGP4, reliant on B* parameters for drag term in TLE, faces systemic inaccuracies in accounting for spatiotemporal atmospheric density variations. These limitations compromise long-term orbital predictions, necessitating frequent corrective maneuvers and impeding reliable collision risk assessments. The proposed method aims to achieve robust and high-fidelity orbital decay forecasting, thereby improving the accuracy and reliability of long-term satellite trajectory predictions in the increasingly complex LEO environment.

Methodology

Solar flux data is predicted through time series analysis and integrated into the NRLMSISE-00 atmospheric model to calculate altitude-dependent density profiles. TLE is propagated by SGP4 to calculate the state vector, which is then converted to geographical coordinates to align with the requirements of the atmospheric model. The gaussian variation of parameter (GVOP) is introduced to calculate the change in semi major axis, incorporating initial orbital elements and a reference BC of a satellite as inputs.

A nonlinear least-squares fitting algorithm iteratively adjusts TLE to minimize residuals between the propagated and expected states, regenerating updated TLE compatible with standard orbit propagators.

Results and Conclusions

The integrated SGP4-GVOP achieved RMS errors of 3.0 km (GRACE1) and 2.1 km (TANSUO1) in semi major axis for 11 years, illustrating advanced accuracy of orbital decay prediction for LEO satellites. By dynamically calibrating atmospheric drag effects, this approach improves long-term decay analysis, allowing sustainable deorbit strategies critical to the longevity of the satellite mission.