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SELF-CONSISTENT VALIDATION OF STATE VECTORS AND COVARIANCES FOR LEOLABS' LOW EARTH ORBIT CATALOG

Abstract

Reliable tracking of Low Earth Orbit (LEO) objects has become an integral part of any business involving satellite operations. As private operators and governments continue to grow their satellite fleets in LEO, the number of debris and Conjunction Data Messages (CDMs) is expected to grow, increasing the concern for safe satellite operations in such crowded environment.

LeoLabs is a commercial provider of low Earth orbit mapping and Space Situational Awareness (SSA) services with its own global radar network and data platform. LeoLabs' catalog of objects in LEO provides data information including, but not limited to, radar measurements, orbit determination, and conjunction screening. One key service provided by LeoLabs is the generation of state vectors and propagations for its catalogued LEO Residential Space Objects (RSO), with a high-fidelity dynamical model perturbed by estimated uncertainties. State vector covariance information is critical for satellite operators to make decisions regarding whether to maneuver space assets to avoid potential collisions. Therefore, the accuracy of the covariances produced by the LeoLabs' orbit determination algorithm, commonly referred to as covariance realism or consistency, is vital for collision avoidance analysis.

This investigation presents a comprehensive decoupled assessment of LeoLabs covariance calculation methodology, by quantitatively and qualitatively evaluating the residuals yield after propagating priorly generated state vectors and comparing them to incoming radar measurements for a fleet of RSOs in the LeoLabs' catalog. To assess the traceability of LeoLabs' data, the Gaussianity of the propagated covariances, the influence of the propagation time, and the impact of the different building blocks of the algorithm are evaluated by performing a variety of statistical tests.

Analysis on the impact of the age of the state vector on the magnitude of the covariances revealed that the uncertainties of the residuals' distributions are Gaussian for the cases in which the state vectors are generated within no more than 2-days prior to the ingestion epoch of the measurements of interest. This study provides satellite operators with valuable insight to improve on the orbit prediction and collision avoidance for their LEO fleets, as the methodology developed in this study is applicable to any object in the catalog, regardless of altitude, inclination or object type –rocket bodies, payloads or debris–.