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TWO-LINE ELEMENT SETS – PRACTICE AND USE

Abstract

The Two-Line Elements (TLEs) that result from Simplified General Perturbation (SGP4) orbit determination allow rapid, modestly accurate propagation of space object motion. As the only openly available, comprehensive catalog of space objects, the U.S. TLE database supports many technical analyses. However SGP4 is based on the Brouwer theory with a power law density model and reflects the knowledge of the space environment in the 1960's. Additionally, the tracking data used in SGP4 orbit determination has improved in absolute accuracy, and in how the data errors are understood. Over time, there have been numerous studies of TLE limitations, methods for accuracy improvement, for generating a covariance matrix, and various other operational applications. Given the continued importance of the TLE for space activities, we summarize these topics and provide recommendations for the use of newer theories. We begin by examining the technical processes used in SGP4 orbit determination and in the formation and distribution of the TLEs. Originally designed to accommodate computer software and hardware limitations, the TLE format is compact and admits a simple propagation technique (SGP4). Exclusion of the one kilometer tesseral m-daily terms, coupled with the irregular distribution of the tracking stations results in long observation fit intervals for many cases. Likewise, orbital maneuvers and dynamic atmosphere and solar radiation pressure effects are important error sources that are omitted in SGP4. Advancements have been proposed to significantly improve the quality of the existing TLE. Additional terms can be inserted into the SGP4 algorithm with remarkable improvements in accuracy. Researchers have also shown how using either TLE or numerically generated ephemerides as observations in the TLE formation can improve the quality. We find that for TLE ephemerides, the results are dependent on the satellite orbit and type. Conjunction operations, and others, often require a covariance which is unavailable with TLEs. CNES and The Aerospace Corporation have periodically visited the issue of generating a covariance that can be used with TLE operations, and we summarize those efforts. Several applications derive useful information from the TLE catalog. In particular, advances in atmos-pheric density corrections were pioneered by Yurasov and Nazarenko, and others. Their techniques are still valid today and have been extended by several organizations. Finally, we propose the opportunity that exists for reprocessing historical observations with an im-proved satellite theory to improve our knowledge of the space environment.