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APPROACHES TO MAKING BEST USE OF TWO LINE ELEMENTS SETS FOR SATELLITE NAVIGATION AND COLLISION AVOIDANCE

Abstract

This paper will review, summarize, and extend approaches to using USAF Two Line Elements (TLE) for satellite operations. Although the USAF cautions against using TLE's for this purpose, many operators of small satellites have no alternative but to use TLE's. They do not enjoy access to independent observations but they still must avoid electromagnetic and physical interference with other satellites. CNES, ESA, NASA Ames, and others have developed mechanisms to extract more information from TLE's. TLE's are very untrustworthy. The TLE process is opaque. TLE's do not include covariances, which are necessary for conjunction assessment. Measurement uncertainties in the observations used to create TLE's are not revealed. TLE's are often latent by up to days. Lately TLE's are derived from more precise Special Perturbations numerical analysis, but they are still very opaque orbit data. Often the "observations" employed are correlated, derived from sensor local tracking algorithms. Inherent uncertainties are greatly underestimated. Covariances within the USAF process are inflated based on "experience." Observations are sometimes rejected based on analyst experience. The process is not verifiable and arguably not repeatable. These deficiencies are well noted and acknowledged. There have been statistical analyses of TLE's, examining successive TLE releases for satellites of interest. The variations among the releases are assumed indicative of real covariances. CNES, ESA, and Ames develop different statistical approaches. These have been validated for small sets of satellites of interest to the organizations. But they are also inherently untrustworthy for other satellites and orbits. Note that CNES and ESA have access to numerous observations outside of USAF sensors. They do not use TLE's at all. They use USAF Conjunction Data Message warnings only to initiate their own, independent orbit estimation and collision avoidance schemes. Ames does not operate any satellites. We will review, compare, and contrast these approaches. We will also canvass the relevant Low Earth Orbit community to learn of other approaches. We will suggest improvements and the most trustworthy schemes for satellite operators who have only TLE's for their critical navigation and collision avoidance responsibilities.