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COMPARATIVE RELIABILITY OF GEO, LEO, AND MEO SATELLITES

Abstract

Reliability has long been an important consideration in the design of satellites and space systems, and in more recent years it has become an essential metric in design trade-space exploration and optimization. However, there is a lack of precise analyses in the literature based on actual flight data: models often use exponential distributions (i.e. constant failure rates) that have been shown unrealistic for modeling spacecraft reliability, and more precise models using flexible Weibull distributions (i.e. not constant failure rates) are not always based on flight data analysis. As a consequence, the authors have already conducted a study to develop a Weibull model of the satellite reliability based on real and recent failure data over a representative sample of Earth-orbiting satellites.

In this paper, this reliability work is applied to compare reliability levels of Earth-orbiting satellites as a function of orbit type, divided into categories of geosynchronous orbits (GEO), medium Earth orbits (MEO), low Earth orbits (LEO) and eccentric orbits (when the orbit eccentricity is too high to classify the satellite in any one of the previous categories). Using the SpaceTrak® database, a life data analysis is conducted over a sample of representative satellites launched between 1990 and 2008. Because our dataset is censored (for example, some satellites are still operational at the end of our observation window), the Kaplan-Meier estimator is used to estimate the reliability function, which is fitted with a two-parameter Weibull distribution. Also, confidence intervals can be derived for the estimated reliability.

As the result of the statistical tool developed previously and described above, we discuss the reliability trends according to the altitude and orbit type of the satellites. Plots of satellite reliability as a function of orbit altitude are provided, as well as confidence bounds on these estimates. It is intended that this information will help inform reliability decisions on the design of Earth-orbiting satellites, and work following this paper may explore further implications of the SpaceTrak® database for different spacecraft inclinations and missions.