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ELECTRIC PROPULSION ANOMALIES AND FAILURES: ANALYSIS OF ON ORBIT TRACK RECORD

Abstract

The adoption of electric propulsion (EP) on board spacecraft has steadily increased over the years, with a compounded average growth rate of about 16% since 1995. EP has been used on orbit for over three decades, principally for station keeping, in conjunction with traditional chemical propulsion for orbit-raising. Despite the advantages it provides (e.g., higher specific impulse and significantly lower mass than chemical propulsion), electric propulsion will not be widely adopted until two fundamental analyses have been conducted and questions addressed. First a value analysis of EP is needed, integrating the various benefits, costs, and drawbacks (including the much longer flight time to achieve final orbit and the corresponding revenues forfeited for example for a communications satellite), and benchmarking it against chemical propulsion systems; satellite operators will make value-informed decision regarding the adoption (or not) of EP, and it is important to understand under what conditions, and for what missions and markets, would EP tip the value balance in its favor. Second, a reliability and risk analysis of EP is needed, and again benchmarking it against the reliability of chemical propulsion systems; satellite operators (and insurers) will also make a risk-informed decision regarding the adoption of EP. In this work we address the second question, and we examine the on orbit track record of all anomalies and failures of electric propulsion (the first question is examined in a companion article). The Spacetrak database is used to collect all EP anomalies and failures experienced on orbit to date. We provide a brief discussion of this complete set of EP anomalies, and then we examine various statistics related to them, including their frequencies (by satellite platforms, orbits, and other covariates), as well as the time to anomaly and the average failure rates (of various severities). We identify important trends in the data, including the presence of infant mortality (which has important implications for subsystem testing). We also analyze the loss of spacecraft service life due to EP anomalies (the results are unexpected and consequential, especially for EP redundancy allocation) as well as the resulting insurance payoffs and losses. Finally, we explore the suitability and limitations of various parametric fits (distributions) for the reliability of EP given the current size and quality of the actual field data (n = 44).