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PROTOS: A POWER SIMULATION AND OPTIMIZATION TOOL TO PREDICT AND EXTEND THE MISSION LIFE OF THE RAPIDEYE SATELLITES

Abstract

Planet owns and operates the RapidEye constellation, which consists of five Earth observation satellites in sun synchronous orbits, phased to provide a daily revisit capability to regions between +/-84 degrees latitude. Collectively, the constellation records approximately 5 million square kilometers of high resolution multispectral imagery per day and has been in continuous operation for the past 8 years. The satellites are expected to maintain nominal operations until their Lithium-Ion batteries reach approximately 50% of their original 15 Ah capacities, at which point they will continue to function but in a degraded operational mode. As the satellites have now exceeded their 7.25 year design life, it is becoming increasingly imperative to accurately estimate their remaining battery capacities and develop a comprehensive strategy to maximize their operational life times.

PROTOS is a tool developed by Planet to calculate the current state of the RapidEye satellite power systems and simulate different operational scenarios and their impact on the capacity fade of the batteries. The tool uses a Kalman filter to estimate the depth of discharge (DoD) of each battery, combining Coulomb counting measurements with battery voltage telemetry. The original RapidEye battery manufacturers, ABSL, produced a set of battery fade plots which project the theoretical degradation of the batteries under certain operational conditions (i.e. number of cycles, maximum life average DoD, maximum battery temperature). PROTOS combines these idealized capacity fade predictions with actual battery temperature telemetry and the calculated DoD values to develop a linearized battery capacity fade model which estimates the "mission life" of each satellite, the date when each battery reaches 50% capacity.

PROTOS is also designed to test various operational scenarios and their impact on the satellite mission life. It contains a spacecraft power simulator developed to emulate the generation, storage and consumption of power onboard the RapidEye satellites. Mission parameters, including the duration, frequency and latitude of data recordings, downlink timing, heater and propulsion usage, etc., were used as design variables and mapped back to the duty cycles of specific satellite subsystems. Constraints were selected for each parameter to ensure solutions met certain minimum mission criteria, such as daily coverage area, temperature limits, etc. Finally, a genetic algorithm was used in conjunction with PROTOS to optimize the design parameters for maximum mission life. Based on this optimized solution, the RapidEye data collection strategy was modified to mitigate battery fade, resulting in an estimated 15% increase of satellite mission life.