Analytical Model of the Van Allen Radiation Proton Flux for Applications in Low-Thrust Trajectory Optimization

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As electronic propulsion systems such as ion thrusters, arc jets, and Hall thrusters become more powerful and able to produce more thrust, they become a much more enticing mechanism to transfer a spacecraft from an initial injection orbit to its final orbit. This means that designers and operators will be able to utilize electric propulsion in order to drastically improve fuel efficiency and by extension make lighter payloads. However, with this increased fuel efficiency there is also a few drawbacks, mainly in that the lower thrust generated by the electric systems require a much longer time-of-flight to move from the lower initial orbit to the higher goal orbit. This longer time spent in the transit introduces a new wrinkle when it comes to calculating the optimal transfer trajectory and is due to the presence of the Van Allen radiation belts. As the spacecraft moves through these regions that surround Earth, it is impacted by thousands of particles which can damage the exposed solar arrays, limiting the amount of power that is able to be generated and therefore decreasing the amount of thrust produced. Chemical propulsion fueled transfers minimize the effects of solar array degradation due to the particles within the Van Allen belts by firstly utilizing a very quick transfer time and secondly by keeping the solar arrays stowed and shielded during the transfer. Lowering of power output capacity and therefore lowering of maximum available thrust will also lead to longer transfer times which lead to more damage and so on. In order to more accurately account for this in an all-inclusive optimization scheme, numerical data is taken from the latest available source, the newly released Ap9/Ae9 measurements, and is then used to determine a simple analytical expression for use within the optimizer that will allow for quicker computation and more accurate trajectory designs. Communications satellites, due to their large power requirements to perform their mission, can possibly support the use of multiple thrusters during the transfer when power generation for its mission is not necessary, making them ideal candidates for all-electric orbit raising. Due to this, the application for this method will be limited to transfers ranging from Low Earth Orbit (LEO) to Geosynchronous Orbit (GEO).