Predicting Magnetospheric Relativistic >1 MeV Electrons

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There is an association between High-Intensity Long-Duration Continuous AE (HILDCAA) activity intervals and the acceleration of relativistic >1 MeV electrons in the magnetosphere. All of the HILDCAAs that occurred in solar cycle 23 (SC23) from 1995 to 2008 led to the acceleration of E>0.6 MeV, >2.0 MeV, and >4.0 MeV electrons in the Earth's outer radiation belts. What is particularly noteworthy is that the E>0.6 MeV electron acceleration was delayed ~1.0 day after the onset of the HILDCAA event, the E>2.0 MeV electrons delayed ~1.5 days after the onset of the HILDCAA event, and the E>4.0 MeV electrons delayed ~2.5 days after the onset of the HILDCAA event.

Because relativistic electrons can be damaging to spacecraft in Earth orbit, knowledge of future enhanced radiation will allow spacecraft engineers to "safe" their spacecraft from the upcoming radiation. The investigators worked to understand if it was solar and interplanetary forcing that was causing the radiation near Earth. A likely scenario is that high-speed solar wind streams come from coronal holes on the Sun. The embedded Alfvén waves in the solar wind plasma cause reconnection of magnetic fields on the dayside of the Earth's magnetosphere, and the solar wind convects the fields and plasma to the tail. After the magnetic fields reconnect in the tail, the plasma is heated as it is injected into the nightside region of the magnetosphere. The energetic ~10 to 100 keV electrons generate electromagnetic waves called chorus waves, which interact with the ~100 keV electrons to accelerate them to ~MeV energies. Interplanetary space data and solar information gathered from NASA, ESA, and NOAA satellites were used to solve the problem.

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Optimal Prioritized Actuator Allocation

This allocation could improve the safety and autonomy of missions where it is critical to match torque first to minimize disturbances to spacecraft pointing.

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For formation flying, rendezvous and docking, and proximity operations with small bodies of the solar system, spacecraft require simultaneous translational and rotational agility. The necessary agility is generally provided by combinations of multiple small thrusters and torque-only actuators. To use these actuators, an onboard control system first calculates desired forces and torques that cause a spacecraft to follow a desired trajectory. Then the commanded forces and torques are turned into individual commands to specific actuators such that the combined action of all the actuators realizes as closely as possible the commanded forces and torques. This problem is referred to as actuator (or control) allocation.

Actuator allocation is fundamentally a constrained optimization problem: given the actuator configuration, find individual actuator commands that minimize the difference between the desired force and torque, and the total force and torque resulting from the individual actuator commands. Mission constraints and in-flight failures limit the configuration of actuators on a spacecraft, in turn limiting the ability to achieve the commanded forces and torques. Further, off-nominal situations can result in commands that require more agility than the actuators can provide. When a desired maneuver exceeds the capabilities of the actuators, it is often more important to maintain pointing — that is, prioritize torques — so translational engines stay pointed in the correct direction and appendages do not strike other bodies.

Prioritized allocation is achieved by solving three or more successive optimization problems instead of the standard two. This approach extends Bodson's framework, where the principal novelty is to explicitly prioritize — rather than weight the force and torque components — by introducing additional, successive optimization problems. The new approach consists of solving each level of prioritization with a constraint that ensures the performance of the preceding optimizations is maintained. For example, first match the commanded torque as closely as possible. Then a second optimization problem is solved that minimizes the error between desired and allocated force with an additional constraint that maintains the optimal torque-matching performance from the first optimization problem. In this way, torque is prioritized over force. Finally, the overall actuator command vector is minimized as in the standard approach. In all optimizations, the maximum impulse constraint is also enforced.

The explicit prioritization developed here is different than weighting. Weighting will not give best torque followed by best force, but rather, 99% best torque and conceivably very poor force matching since it is de-weighted. Further, the approach is generalizable to any prioritization of the six degrees of freedom; for example, when near the surface of a small body matching