THE FEASIBILITY OF MULTIPOLAR ELECTROSTATIC RADIATION SHIELDING

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BACKGROUND TO ELECTROSTATIC SHIELDING
Because interplanetary space radiation is approximately isotropic, it has been assumed in previous studies that an electrostatic radiation shield must have radial symmetry. Unfortunately, an outwardly-repulsive radial field sufficiently strong to deflect energetic protons would inadvertently attract a much-larger flux of thermal electrons, imparting to them sufficient energy to generate a critical bremsstrahlung hazard. In these previous studies, it has therefore been assumed that a region of negative electrical charge must be maintained at a substantial radial distance around the spacecraft to terminate the outwardly-positive field. This could be accomplished by deploying a spherical, conductive grid around the spacecraft, which would entail a large mass penalty, or by trapping a cloud of electrons with a large magnetic field (the Plasma Shielding concept). Both approaches have significant drawbacks, and as a result it has been generally concluded that electrostatics is not a practical or mature approach for shielding.

A NEW CONCEPT: MULTIPOLAR ELECTROSTATIC SHIELD
We have recently observed \cite{1}, however, that the physics and the shielding problem possess certain asymmetries which may be exploited in order to obtain the intended shells of isotropic protection without deploying radially-symmetric charge around the spacecraft. The basic concept is to leverage a multipole expansion of the fields, assigning a different function to different terms in the expansion. As shown in Fig. 1, a positively-repulsive quadrupole term may protect the region closest to the spacecraft from high-energy protons and HZE particles, whereas a weaker but slowly decaying monopole field may deflect thermal electrons away from the larger region of space. The result is that the significant fluxes of both negative and positive particles may be deflected away from the spacecraft using the same electrostatic field. This has the potential to create isotropic protection with a significant reduction in spacecraft mass.

FEASIBILITY OF THE CONCEPT
In this paper we present the concept and discuss its feasibility for interplanetary spacecraft applications. Computer simulations of this shielding concept have been performed in order to predict scattering trajectories of electrons, protons and HZE particles. (See, for example, Fig. 2.) Shielding efficiency has been calculated for several configurations. As a particular case, the radiation environment encountered during the Jupiter Icy Moons Mission has been considered. One technological challenge is the design of a power supply adequate to achieve the needed voltages and currents, which seems feasible due to the high vacuum breakdown voltage of the space environment. A second issue is integration of a shielding system with ion propulsion engines. These issues are discussed and possible solutions are presented.

REFERENCES
\cite{1} Metzger, P.T., Lane, J.E., and Youngquist, R.C. (2004)

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{multipole}\caption{Multipolar electric potential normal to the long-axis of the spacecraft.}
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\begin{figure}[h]
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\includegraphics[width=0.5\textwidth]{trajectories}\caption{Electron trajectories showing repulsion by the monopole term of the field.}
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