Natural Environmental Shielding Impacts on Spacecraft Electronics and Sensor Shielding Design for Missions to Extreme Radiation Environments of Europa and Ganymede

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Artificial shielding requirements significantly drive planetary spacecraft electronics and sensor mass, risk, and cost for extreme radiation environment destinations but are overestimated if natural shielding factors by planetary bodies, surface topography, and magnetic fields are not fully taken into account. The well-known hemispheric asymmetry of MeV electron irradiation on the surface of Europa [Paranicas et al. 2001, 2009; Patterson et al. 2012] arises from gradient curvature drift effects in which only high-intensity electrons below 20 MeV can impact the apex of the trailing hemisphere while only low-intensity electrons at higher energies impact the leading hemisphere. A low-altitude polar orbiter mission to Europa would experience in orbit lower average dose rates than elsewhere near Europa's orbit around Jupiter. Our 2012 - 2014 Goddard study for a small low-cost Europa orbiter has shown that mission dose including three months in orbit could be comparable to NASA's 2012 descope design for the multiple-flyby Europa Clipper mission, even though the Jovian system trajectory of the latter is designed to minimize shielding requirements for radiation-sensitive systems. Radiation noise in electronics and sensors for science observations can also be minimized for selected flyby or orbiter passes away from the trailing hemisphere. A landed mission near the leading apex of Europa would experience orders of magnitude less radiation than elsewhere on the surface, which would also be highly beneficial for detection of recognizable chemical signatures of inorganic and organic materials at the landing site from the putative subsurface ocean. If a Europa lander could be targeted to the electron radiation shadow of a local topographic feature, the spacecraft radiation dosage would be further reduced and more pristine endogenic materials might be found. Since the equatorial magnetic field of Ganymede is sufficient to deflect essentially all Jovian energetic electrons away from altitudes less than a few hundred kilometers above the surface [Cooper et al. 2001], all missions there would have reduced dosages from both the natural magnetic and body shielding effects. Radiation noise to electronics and sensors, and total dosages to all systems, electronic and biological, would be enormously reduced near the Ganymede magnetic equator for low-altitude orbiters, flybys, landers, and even human exploration or commercial endeavors.

References

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