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The Dynamic Interplay Between Spacecraft Charging, Space Environment Interactions and Evolving Materials

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Abstract

Nothing endures but change. *Heraclitus of Ephesus* (c. 495 BC)

The charge on spacecraft is constantly changing, as a result of the dynamic nature of the space environment, the spacecraft orbit, the interactions between environment and spacecraft, and even the spacecraft materials. While the effects on spacecraft charging from varying environmental conditions and from the selection of different construction materials have been studied extensively, the modification of material properties by the space plasma environment can also have profound effects on spacecraft charging. Given the increasingly demanding nature of space missions, there is clearly a need to extend our understanding of the dynamic nature of material properties that affect spacecraft charging and to expand our knowledgebase of materials' responses to specific environmental conditions so that we can more reliably predict the long term response of spacecraft to their environment**.** Indeed, Ferguson recently identified non-static spacecraft materials properties and dynamic spacecraft charging models as two of four "New Frontiers in Spacecraft Charging", critical to the advancement of the field over the next decade.[†]

This presentation focuses on measurement methods and modeling employed to assess the effects of environment-induced material modifications on the physical properties used as input parameters for spacecraft charging simulations. It also reviews several specific studies in which environment-induced material modifications have had significant impact on predicted spacecraft charging. We present an overview of testing and modeling conducted by the Utah State University (USU) Materials Physics Group and other investigators. These tests quantify the changes in charging, discharging and emission as material properties are modified by variations in temperature, charge accumulation and electrostatic fields, radiation dose and damage, surface modifications including roughening and contamination, and the duration, rate and history of imposed environmental test conditions. Such changes have been shown to affect measurements of the following material properties: electron-, ion- and photon-induced electron emission yields, spectra, and yield decay curves; dark current and radiation induced conductivity; electrostatic discharge and charge decay curves; electron-induced surface charging, discharge and luminescence; and UV/VIS/NIR reflectivity, transmissivity, absorptivity, and emissivity. Considerations in incorporating evolving materials properties into dynamic models of the accumulated charge distributions and transport properties are also discussed. Examples are given from recent USU studies related to several specific missions, including the 2005 concept of the Solar Probe Mission, the James Webb Space Telescope, and potential polar and Jovian missions.

We end with a discussion of how a broader materials knowledgebase and a conscious awareness of the dynamic nature of materials can be used in concert with the available modeling tools to anticipate and mitigate potential spacecraft charging problems.

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[†]D. Ferguson,"New Frontiers in Spacecraft Charging," *IEEE Trans. Plasma Sci.*, **99**, 1-5, 2012.

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