CubeSat Susceptibility to Auroral Space Weather Events

Emily M. Willis[1], Joseph I. Minow[1], L. Neergaard Parker[2]

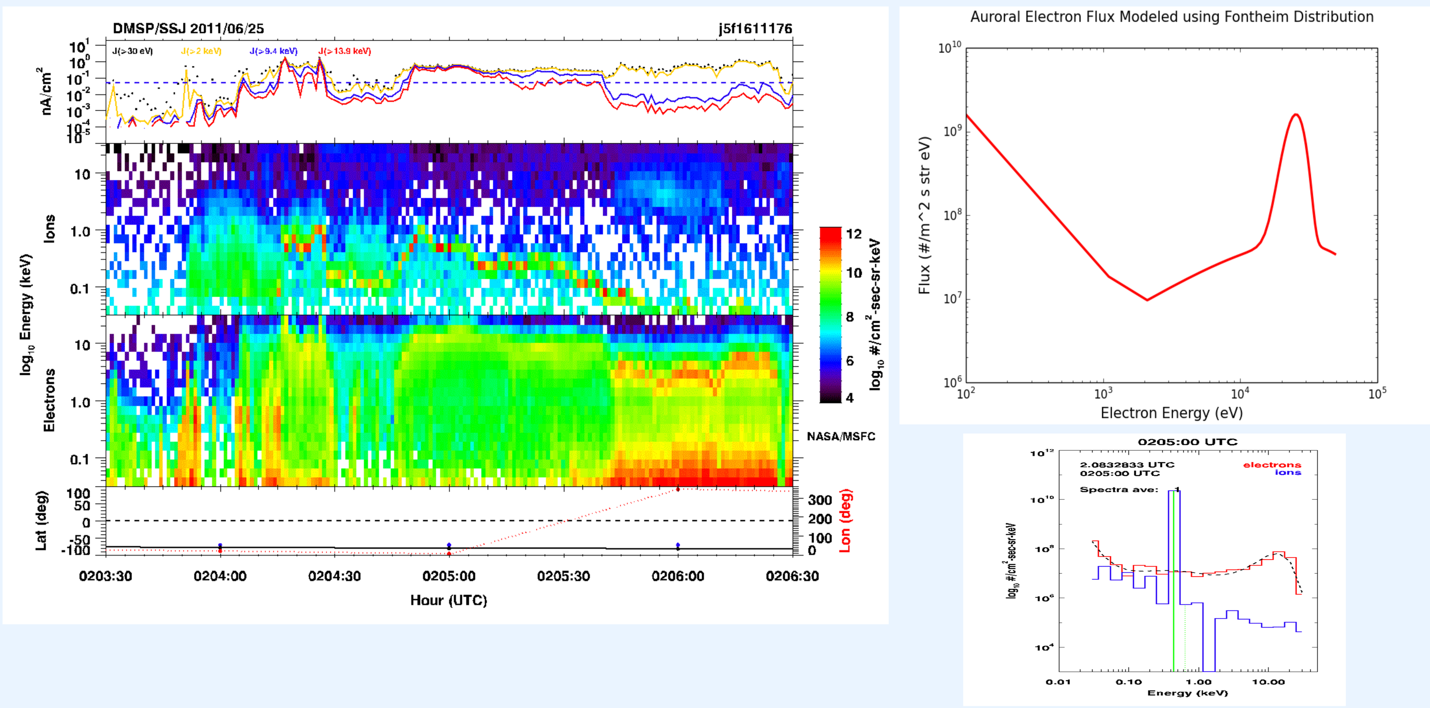
JACOBS ESSSA Group

[1]NASA, Marshall Space Flight Center, Huntsville, AL
[2]Jacobs , ESSSA Group, Huntsville, AL

Background

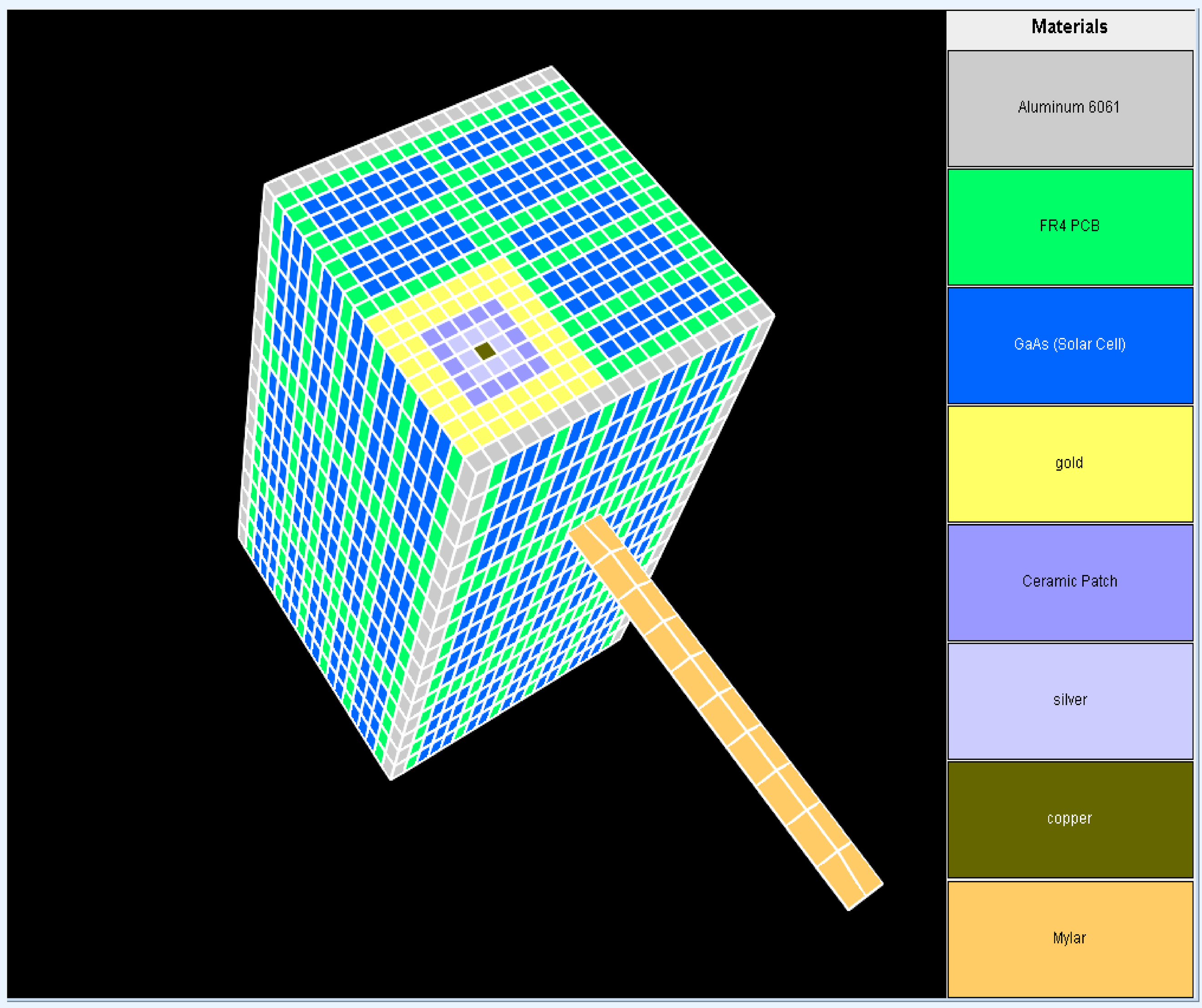
The demand for CubeSat missions continues to grow as government, academic, and commercial programs seek quick-turnaround, low cost access to space. As the complexity of CubeSat missions increases, it is becoming more and more important to consider the effects of space weather on these small satellites. CubeSat projects, however, usually do not have the time or funding to include thorough analysis due to their low budget and quick-turnaround requirements. CubeSat projects also tend to rely heavily on commercial "off-the-shelf" products, many of which are not qualified for use in space, and are particularly vulnerable to the effects of the space environment. Spacecraft charging occurs when charged particles from the surrounding space plasma environment contact a spacecraft and unequal charging currents result in a net charge density accumulation on or in spacecraft materials. Charging becomes a threat when differential potentials between two points on the spacecraft or between the spacecraft and the ambient space environment generate electric field levels exceeding the electric breakdown strength of the spacecraft materials. Electrostatic discharge arcs are generated as a result of the large electric fields. Electrostatic discharges resulting from spacecraft charging can adversely affect telemetry and cause irreparable damage to electronics. Other spacecraft charging effects include damage of solar arrays and thermal protection, enhancement of contamination of surfaces, and degradation of optics.

Auroral Electron Environment



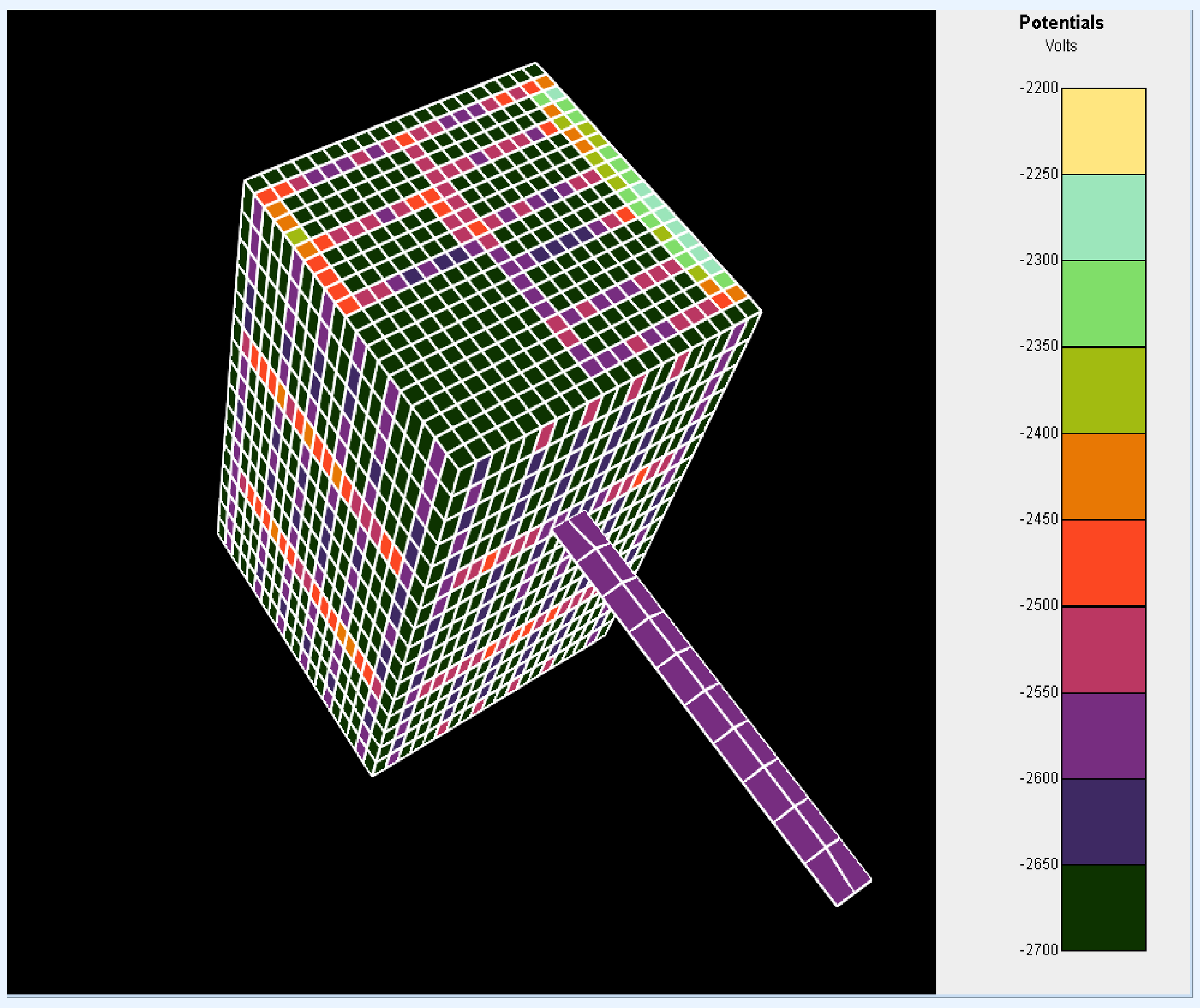
Spacecraft charging in LEO is typically not a concern due to the high density, low energy plasma. However, if the spacecraft inclination is high enough to reach polar latitudes, spacecraft surface charging can be a significant issue due to the high energy electrons that precipitate down from the open magnetic field lines present in the auroral region. The charging is expected to be highest when the precipitating electron flux is coincident with lower density plasma conditions, such as is observed during times of low solar activity and orbit eclipse. The energetic auroral electrons can be modeled as a Fontheim Distribution[1] using inputs based on data collected from the DMSP satellite.

CubeSat Model



Nascap-2k[2] is a software package which calculates the accumulation of charge on spacecraft surfaces in a specified space plasma environment. The standard information regarding materials required for a spacecraft charging analysis is not widely available for the COTS products used in CubeSat designs, which makes it difficult to obtain an accurate charging analysis. Therefore, the materials must be either tested or the values estimated. This model incorporates materials typically used in low-budget CubeSat Projects[3]. The structure chassis is made of hard-anodised and alodined aluminum. The structure is covered with GaAs solar cells mounted on FR4 PCB. A monopole "measuring tape" antenna, which is a Mylar coated steel tape, is mounted on the side of the structure, and a patch antenna is on top. The patch antenna is modeled with a statically dissipative ceramic material.

Nascap-2k Simulation Results



This Nascap-2k[2] simulation was performed using a Fontheim Distribution for an auroral environment. The simulation shows spacecraft charging of over -2kV with respect to plasma. The maximum differential charging between a surface dielectric and grounded conductor is approximately 500 Volts. This differential charging could lead to arcing on the spacecraft, particularly at corners, gaps, or imperfections where the electric fields are highest. For more complex designs with features such as high voltage solar arrays or ion thrusters, the differential charging would be more significant. Mitigation techniques such as conductive coatings over surface dielectrics should be considered for CubeSats destined for a polar orbit. Proper mitigation techniques are well documented in NASA's guidelines for mitigating in-space charging effects[4].

References

[1]Fontheim, E. G, Stasiewicz, K., Chandler, M.O., Ong, R. S. B., Gombosi, E. , Hoffman, R. A, "Statistical Study of Precipitating Electrons", Journal of Geophysical Research, 1982.
[2]Davis, V.A., Mandell, M.J., Jongeward, G.A., "Computing Surface Charging In The Auroral Environment Using Nascap-2k", AFRL-VS-TR-2003-1606, 2003.
[3]www.CubeSat.org
[4]NASA-HDBK-4002A, "Mitigating In-Space Charging Effects -A Guideline", 2011.

Contact Information
Emily Willis (emily.willis@nasa.gov)