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electro magnetic applications, inc.

Simulation of Spacecraft Charging Threats

Bryon Neufeld and Nicole Pothier McGillivray
Electro Magnetic Applications, Inc., Denver, CO
bryon@ema3d.com

Introduction:

Electrostatic charging due to the interaction of space vehicles with space plasma environments is an important design and safety issue in modern space platforms. We present an approach for the simulation of surface and internal charging. Such simulations are an important part of efficient and accurate vehicle design hardness. We present a new tool, EMA3D-Internal, for performing a thorough evaluation of spacecraft internal charging risks. The tool can be run entirely from the graphical user interface and allows geometry import and development from within the advanced CAE platform. The user can specify an arbitrary and realistic radiation spectrum, such as what might be obtained using the AP9/AE9 framework.

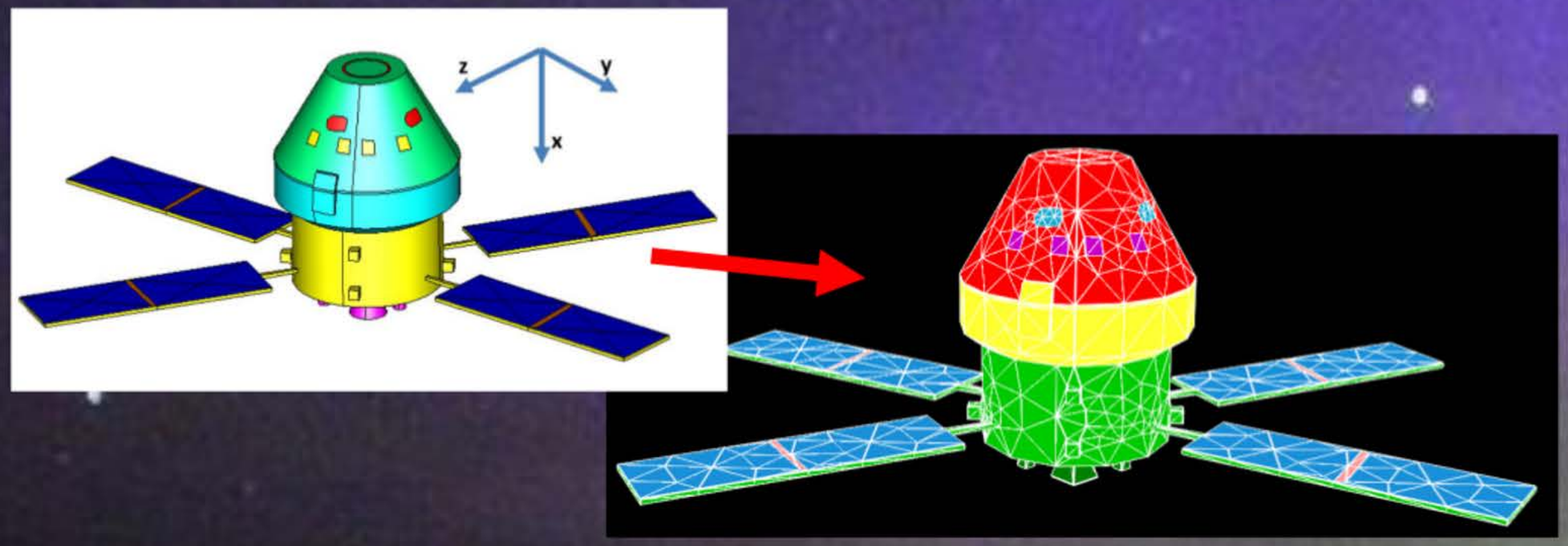

Figure 1: Meshed model for surface charging developed in EMA3D front-end.

Surface Charging: EMA3D/Nascap-2K

The surface charging is performed in EMA3D/Nascap-2K. EMA3D provides a platform for the front-end geometry preparation and the back-end post-processing. Figure 1 shows an example geometry for our simulation. This is an Orion-like vehicle that has been developed in EMA3D, meshed, had materials assigned, and then exported for simulation in Nascap-2K. We will look at the worst case charging in a geosynchronous plasma.

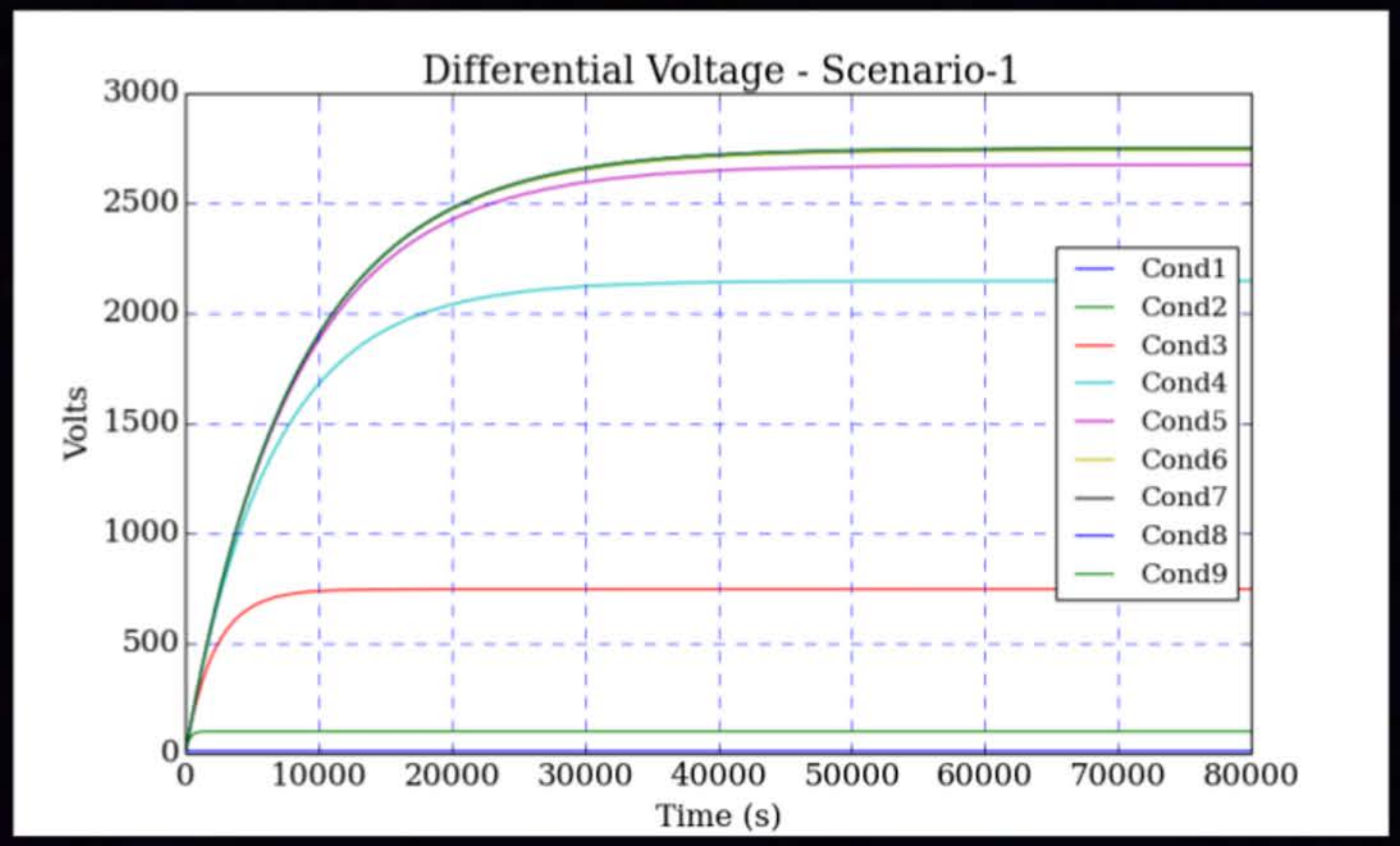

Figure 2: Differential charging between dielectric and conductor as the conductivity of the dielectric is varied. We see a saturation value for the differential charging as the resistivity is increased.

Partial results of our surface charging are shown in Figure 2. The plot shows the time development of differential voltage between the conductor and dielectric as the resistivity of the dielectric is increased. There is a saturating value of the differential voltage as the dielectric becomes more resistive – approaching an open circuit type configuration. Similarly, as the resistivity is decreased, the system approaches a short circuit configuration. The transition for this model occurs between 1e-12 S/m (short) and 1e-16 S/m (open) for the conductivity of the dielectric material.

Internal Charging: EMA3D-Internal

EMA3D-Internal is our platform for internal charging assessment. The internal charging occurs when higher energy electrons penetrate into material, creating an electric field distribution within dielectrics that may result in harmful arcing and discharges.

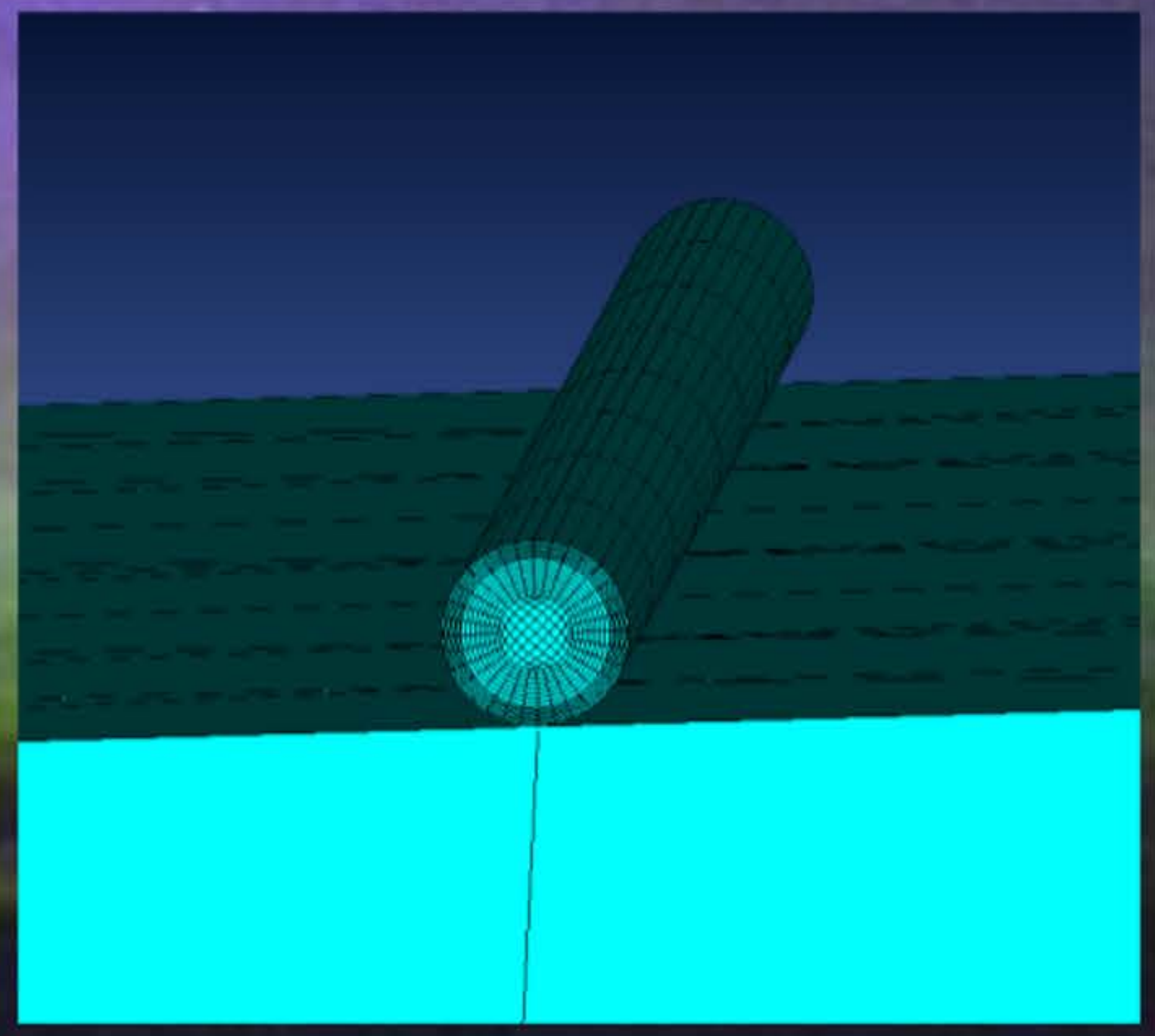

Figure 3: Meshed model for internal charging developed in EMA3D-Internal.

Geometry Interface

EMA3D-Internal uses a powerful CAE platform for the front-end user interface. Geometry import, advanced geometry development and finite-element meshing are all supported in this platform. An example mesh of a cable on a ground plane is shown in Figure 3.

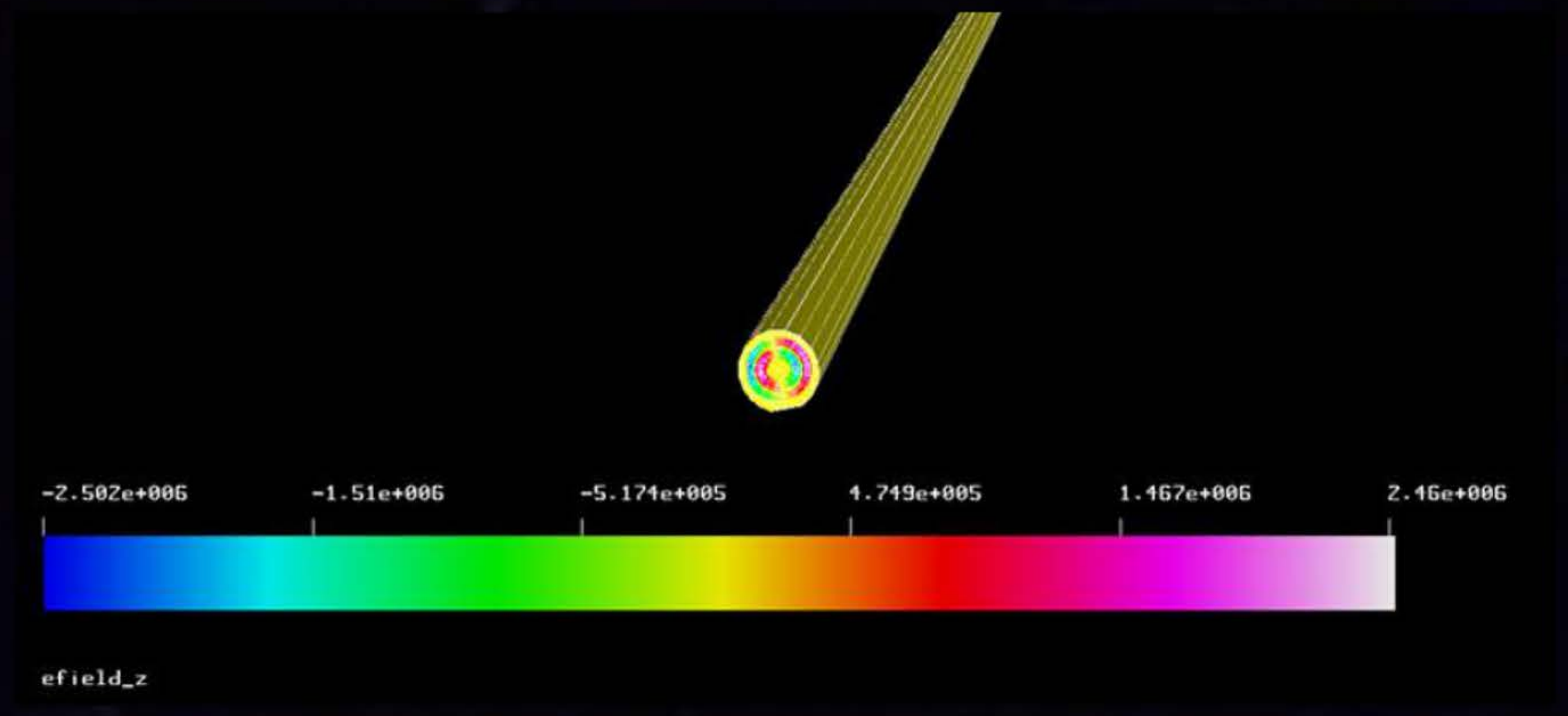

Figure 4: Sample results of internal charging of a cable in EMA3D-Internal.

Particle Transport and Quasi-Electrostatics

Figure 4 shows an example output for the internal charging of a basic cable in EMA3D-Internal. The colors represent the electric field induced (V/m) as a result of the collection of charges within the dielectric materials that make up the cable. The equal and opposite magnitudes within the cable show a transverse component of the electric field. Figure 5 shows output for the internal charging of a basic slab. Charge is deposited using Monte-Carlo particle transport methods in EMA3D-Internal and the resulting time dependent electric field is obtained with a finite element quasi-electrostatic simulation.

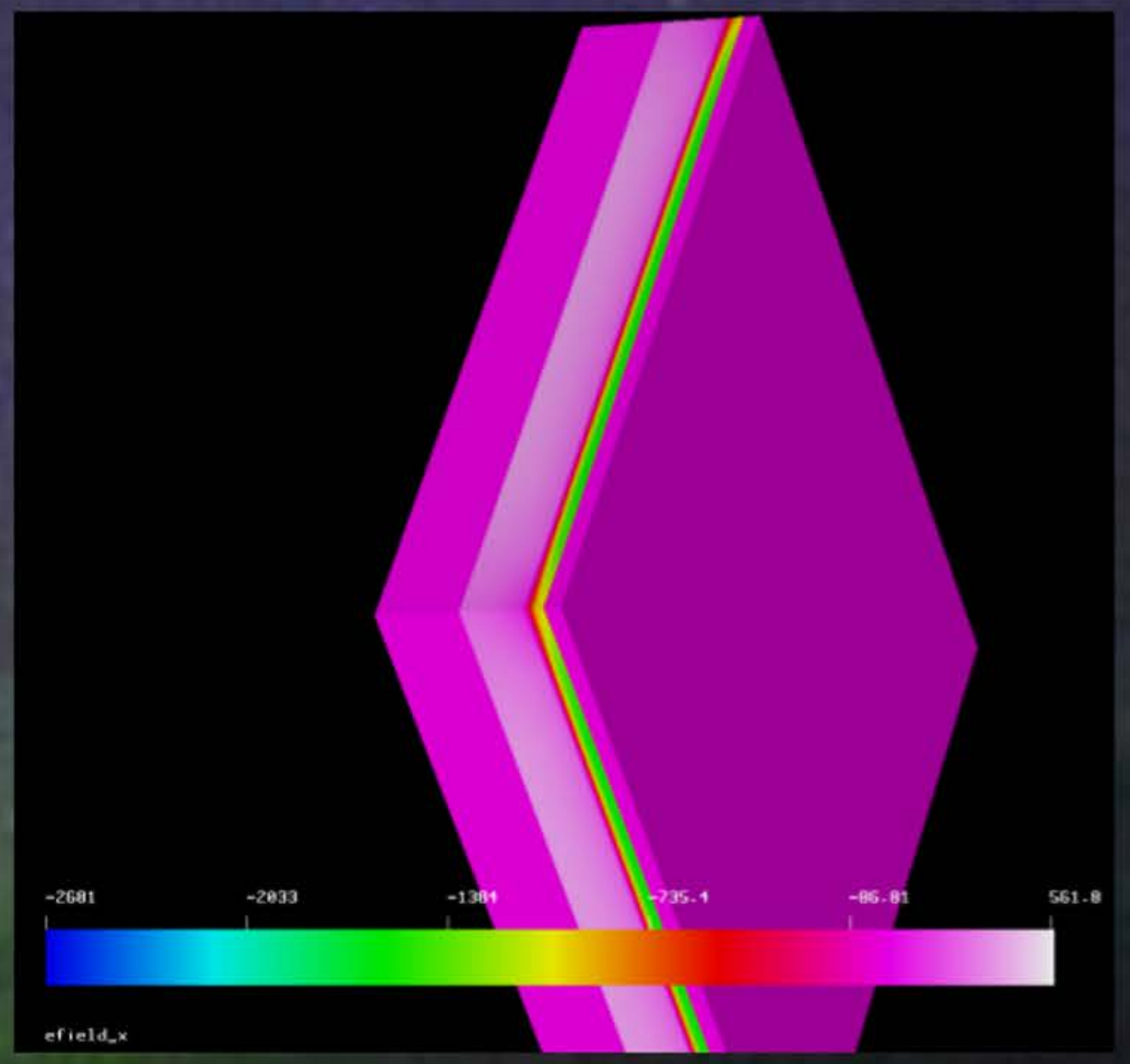

Figure 5: Sample results of internal charging of a simple slab in EMA3D-Internal.

Validation

We compare our results for the simple slab model with results for the same model in NUMIT 2.0. Figure 6 shows the electric field profile for EMA3D-Internal (blue) and NUMIT 2.0 (green).

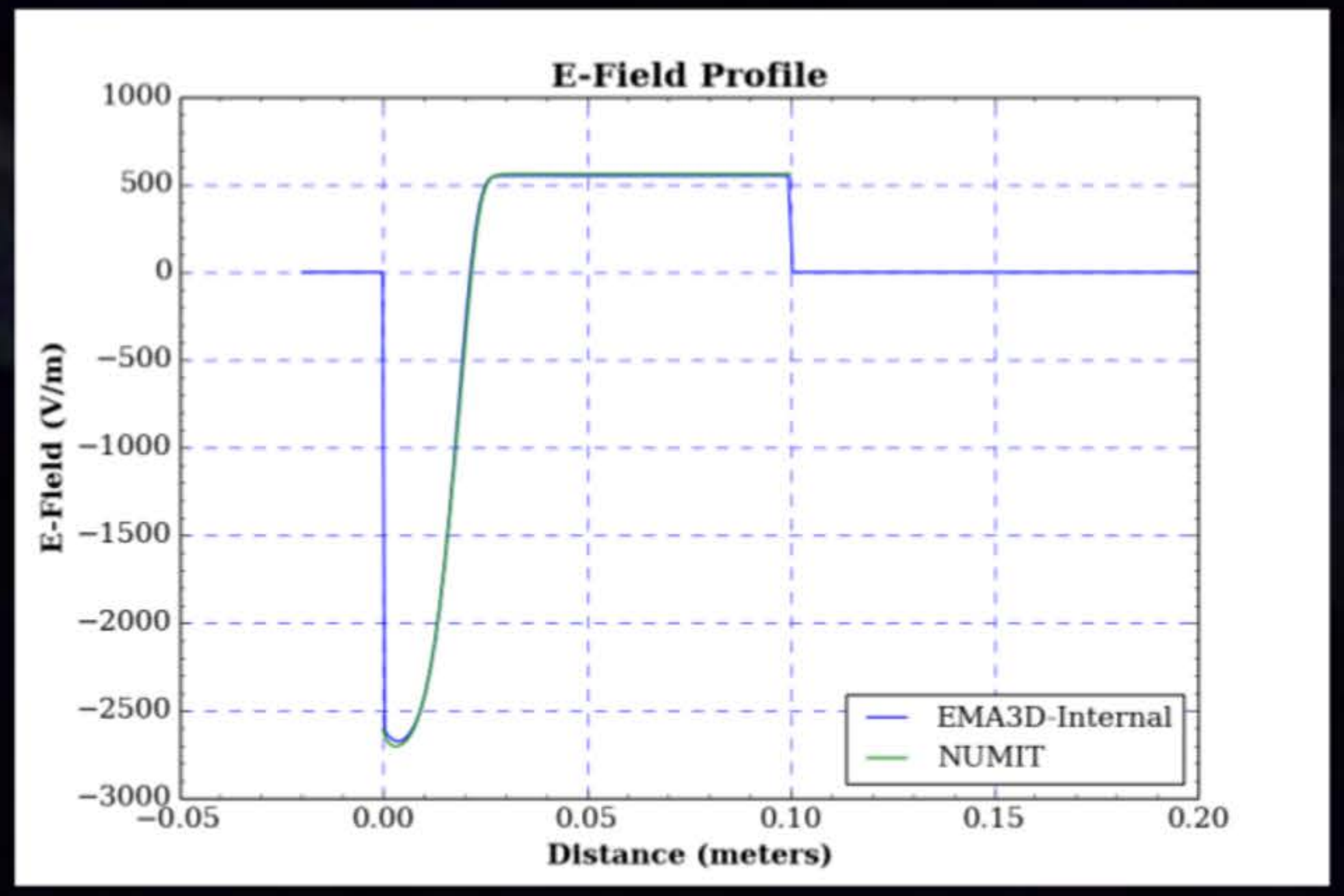

Figure 6: Agreement between EMA3D-Internal (blue) and NUMIT 2.0 (green).

Conclusions:

We have presented techniques for the numerical analysis of space charging threats to space platforms. Theses techniques can help guide the EMI/EMC design and mitigate risk for space vehicles.

References: [1] Nascap-2k User's Manual, Report SAIC 02/2047-R5, [2] Surface Charging Simulations of an Orion-like Spacecraft in a Geosynchronous Space Plasma, Bryon Neufeld, Proceedings of EMC 2016, [3] www.ema3d.com