Automated Software System For The Simulation Of Arcing In Spacecraft On-Board Power Electronics Equipment

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Introduction: The phenomenon of arcing is always associated with a significant energy release, leading to the failure and destruction of on-board equipment. In our project, we propose an innovative software solution to the problem of electrical arcing risk prediction in high-voltage on-board electronic equipment intended for long-term self-contained use, like spacecraft conditions.

Arcing simulation is a monumental challenge because it represents an attempt of numerical solution to the multiscale discharge plasma problem. The main trouble is that the detection of several small regions of possible arcing at large PCB requires incredible computer performance.

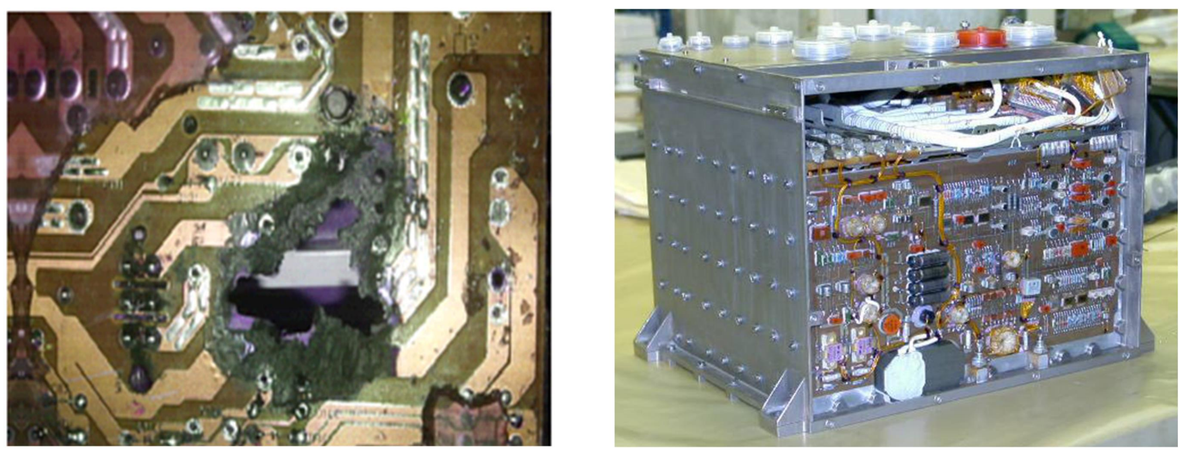

Figure 1. Arcing's consequences

Computational Methods: Based on simultaneous numerical solution of partial differential equations in COMSOL Multiphysics using a Plasma module provides the spatial distribution of the electric field and the plasma components densities in time domain.

$$\frac{\partial n_e}{\partial t} + \nabla \cdot \boldsymbol{G}_e = R_e \qquad \rho \frac{\partial \omega_k}{\partial t} = \nabla \cdot \left(\rho \omega_k \boldsymbol{U}_k \right) + R_k$$

$$\frac{\partial n_\varepsilon}{\partial t} + \nabla \cdot \boldsymbol{G}_\varepsilon + \boldsymbol{E} \cdot \boldsymbol{G}_e = R_\varepsilon \qquad \nabla^2 V = -\frac{q}{\varepsilon_0} \left(\sum_{k=1}^{N} Z_k n_k - n_e \right)$$

$$\boldsymbol{E} = -\nabla V$$

The device design is the combination of the two or more PCBs, surrounded by gas medium and grounded metal casing.

All boundary and initial conditions are applied automatically.

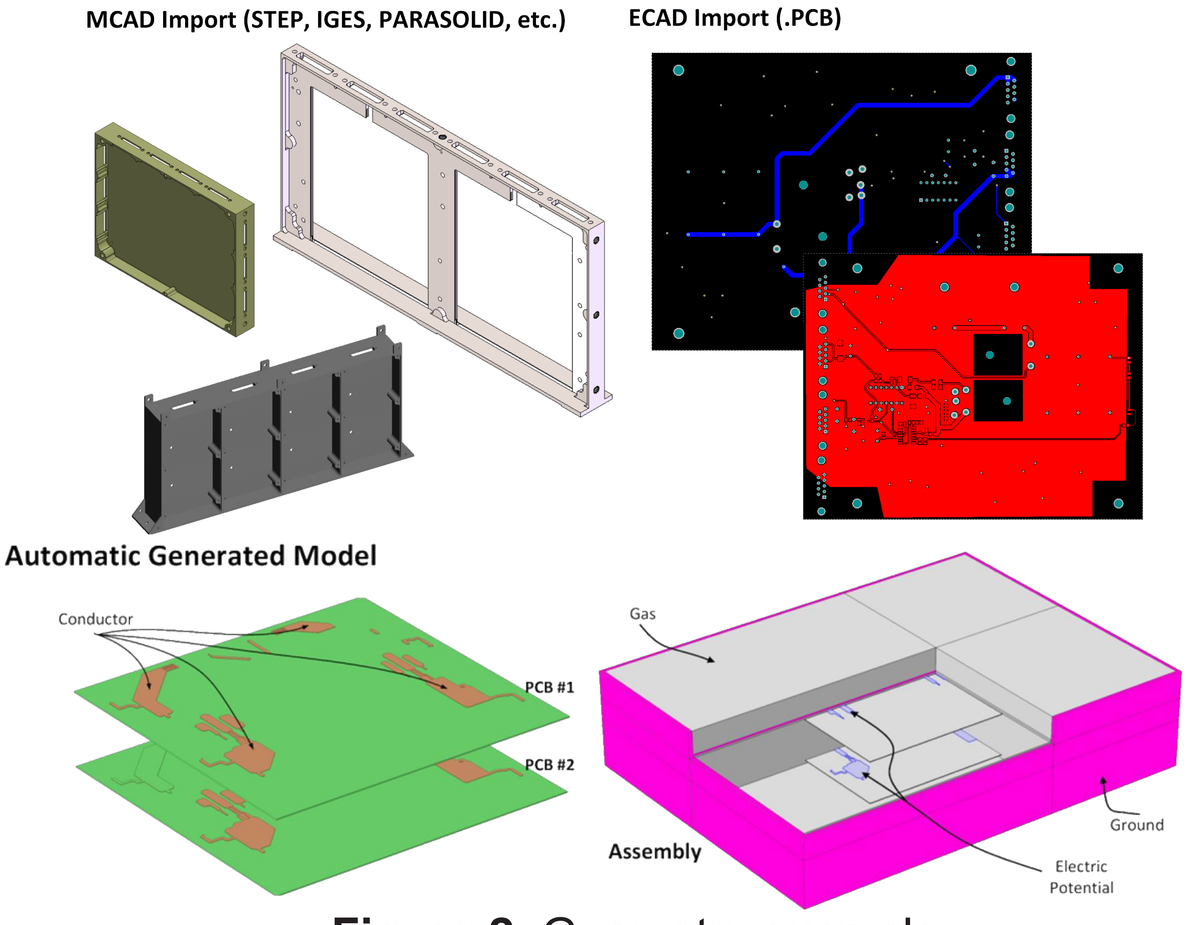

Figure 2. Geometry example

Results: We translates the large-scale 3D-simulation into limited set of fast 2D simulations. The majority of pre- and post-processing operations are automated in order to simplify diagnostics to end user. As a result of computations we obtain the locations of possible electric arcs (critical regions) and critical ranges of operating parameters. We implement the computational methodology in the Application Builder of COMSOL Multiphysics and AC/DC, Plasma and CAD Import COMSOL Multiphysics modules.

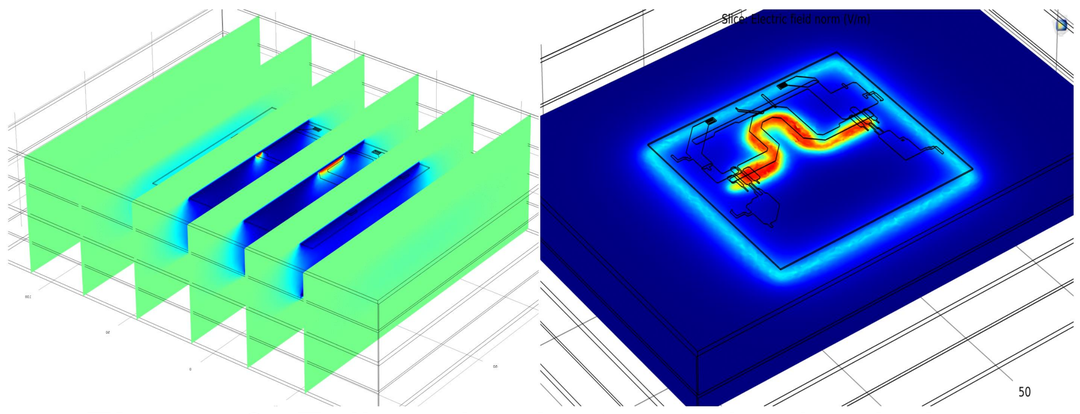

Figure 3. Full-scale electrostatic simulation

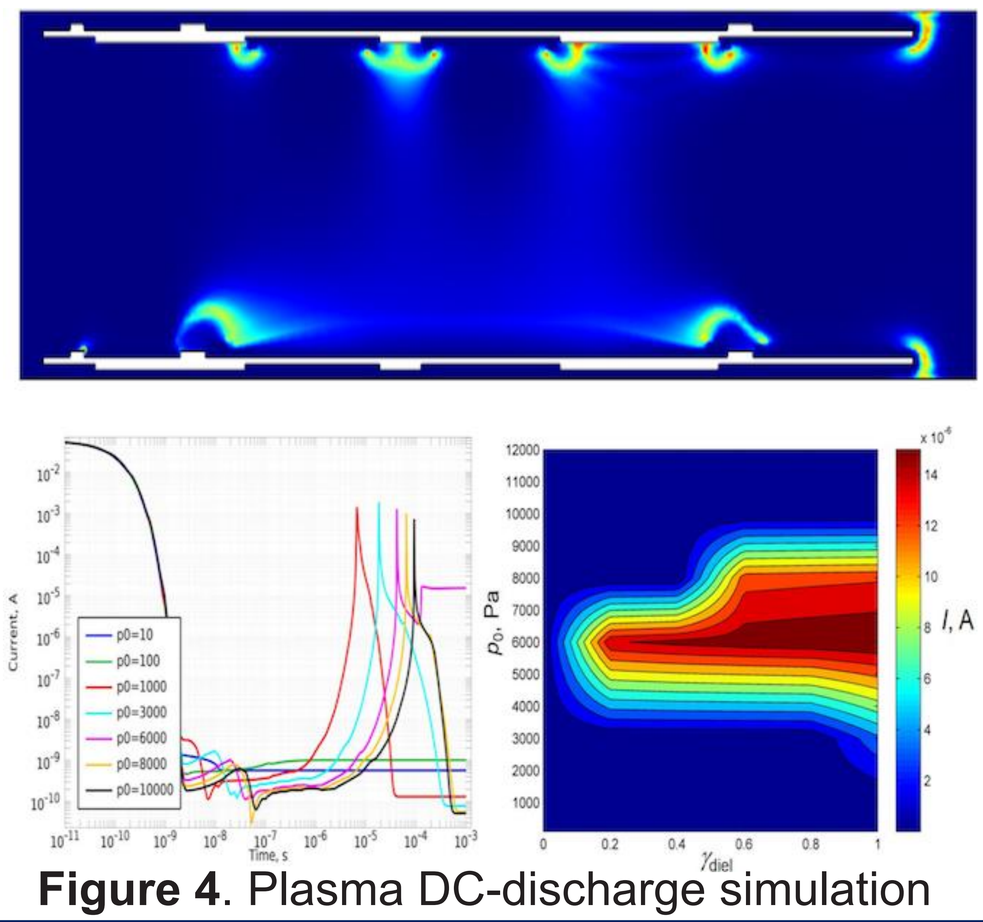

Figure 4. Plasma DC-discharge simulation

Conclusions: There is still work to be done, but our working prototype already can be easily applied to arcing diagnostics of electronic devices operated under wide range of parameters. Some simulation results have been confirmed by experimental studies.

References:

- Design and Diagnostics of Arc-resistant Electronics for Satellite Telecommunication Systems / V.Y. Kozhevnikov, A.V. Kozyrev, N.S. Semeniuk, A.V. Batrakov, V.M. Karaban, D.S. Kosov // 18th Mediterranean Electrotechnical Conference (MELECON-2016), Limassol, Cyprus. – April 18-20, 2016.
- Diagnostics of primary arcing in electronics of satellite telecommunication systems / V. Yu. Kozhevnikov, A.V. Kozyrev, A. V. Batrakov, N. S. Semeniuk, and V. M. Karaban // 23th Telecommunications forum TELFOR 2015, 24-26 November 2015, Belgrade, Serbia, pp. 615-618.

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