Novel Automated Software System for Arcing Simulation in Spacecraft on-Board Electronics

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Abstract

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. As modern on board equipment is not vacuumed the appearance of arcing leads to considerable damages due to high energetic output from arcs. In spacecraft, this problem has been current since 1995 when Boeing Satellite Systems offered the BSS 702 platform with high-voltage bus connected to 100 V stabilized power source. Possible further increase of operating voltages (e.g. due change in standard) will only escalate the problem.

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 several small regions of possible arcing at large PCB location require incredible computer performance. The newest entry in this field is the decomposition approach [1, 2]. Here we propose the software implementation for it. The major effort aims to locate potentially vulnerable regions for complex electronics. Our software allows analyzing various regimes of arcing w.r.t. multiple parameters changes.

We implement the computational methodology in the Application Builder of the COMSOL Multiphysics® software and AC/DC Module, Plasma Module and CAD Import Module. Our designed software consists of "Three-dimensional macro-model" and "Processing core" modules. Simulation starts with "Three dimensional macro-model" providing necessary preprocessing as internal definition/import of device geometry from CAD software, definition of operating parameters, grid meshing, imposition of boundary conditions, etc. PCB layout import is carried out from an electrical computer-aided design system in .PCB format (ASCII). We implement our own data import module using Application Builder to extend import capabilities. Importing of basic 3D geometric structures is available in STEP, IGES, Parasolid®, ACIS®, Inventor®, PTC® Creo® Parametric™, and SOLIDWORKS® formats.

"Processing core" module performs main computations separated into following sequential steps:
1. Electrostatic problem solution for complete device to identify specific field enhancement regions or probable PCB defects (so called "critical regions");

2. Automatic decomposition of the geometrical model from 3D into set of simplified 2D models of critical regions;
3. DC-discharge simulation for each critical region with parametric sweep by a set of parameters (pressure, initial ionization, emission, etc.)

The novel computational algorithm implemented in our software significantly (ten times as compared to full-scale simulation for particular case) reduces computation cost. It makes possible to solve large diagnostic routines without high performance computing. The effectiveness is based on the dimensionality reduction that turns 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. Our working prototype can be easily applied to diagnostics of electronic devices operated under wide range of parameters.

Reference

[1] V. Yu. Kozhevnikov et al., Design and Diagnostics of Arc-resistant Electronics for Satellite Telecommunication Systems, 18th Mediterranean Electrotechnical Conference MELECON 2016, Limassol, Cyprus, p. 1 (2016)
[2] V. Yu. Kozhevnikov et al., Diagnostics of Primary Arcing in Electronics of Satellite Telecommunication Systems, 23th Telecommunications forum TELFOR 2015, Belgrade, Serbia, p. 615 (2015)
[3] S. A. Onischenko et al., Influence of a Thin Dielectric Film on Electrical Insulation in Vacuum Gaps at the Pulse Voltage, 2014 International Symposium on Discharges and Electrical Insulation in Vacuum (ISDEIV), Mumbai, India, p. 49 (2014)
[4] A. V. Kozyrev et al., Theoretical Simulation of a Gas Breakdown Initiated by External Plasma Source in the Gap With Combined Metal-Dielectric Electrodes, IEEE Transactions on Plasma Science, Vol. 43, p. 2294, (2015)

Figures used in the abstract

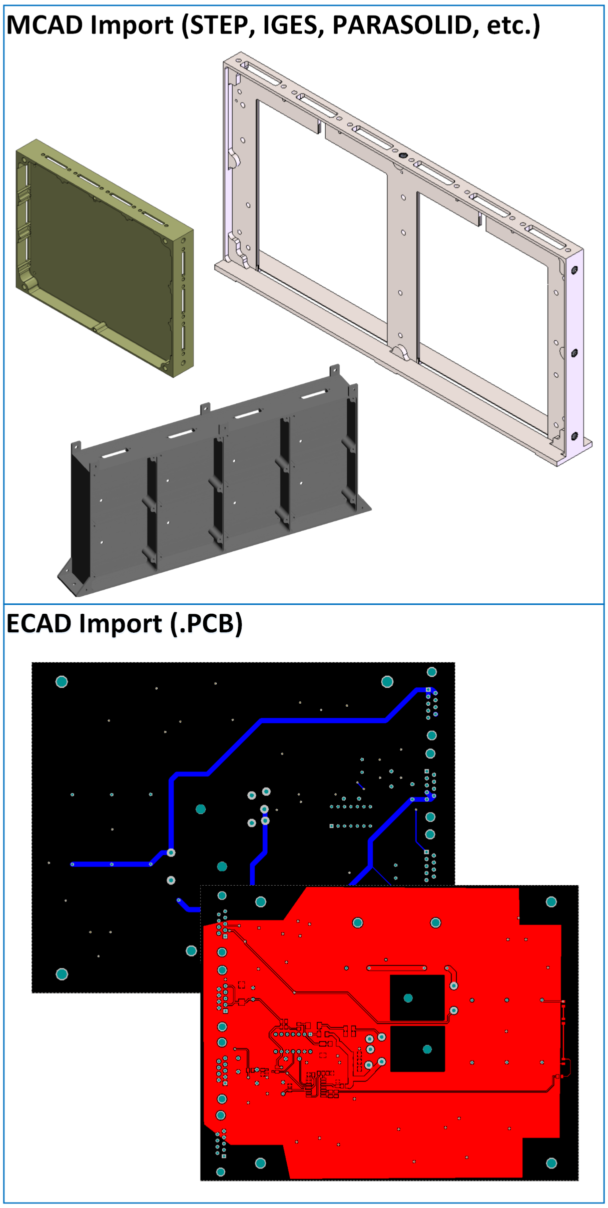

Figure 1

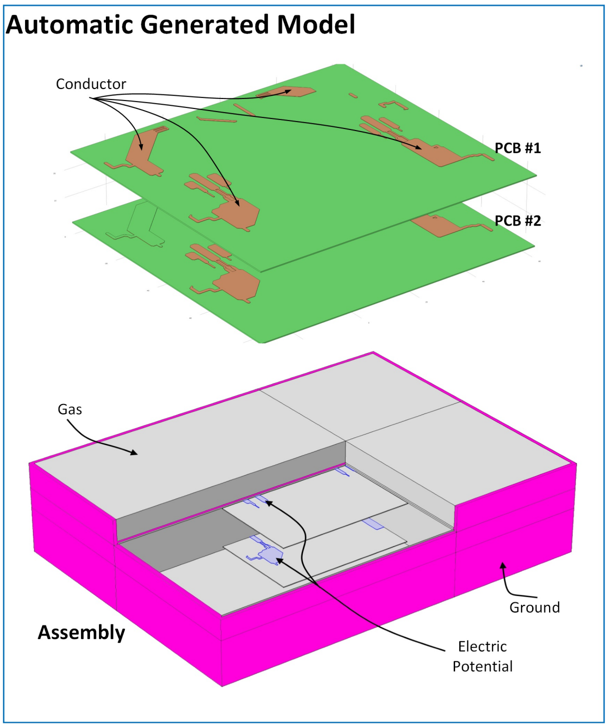
Automatic Generated Model
Conductor
PCB #1
PCB #2
Gas
Ground
Assembly
Electric
Potential

Figure 2

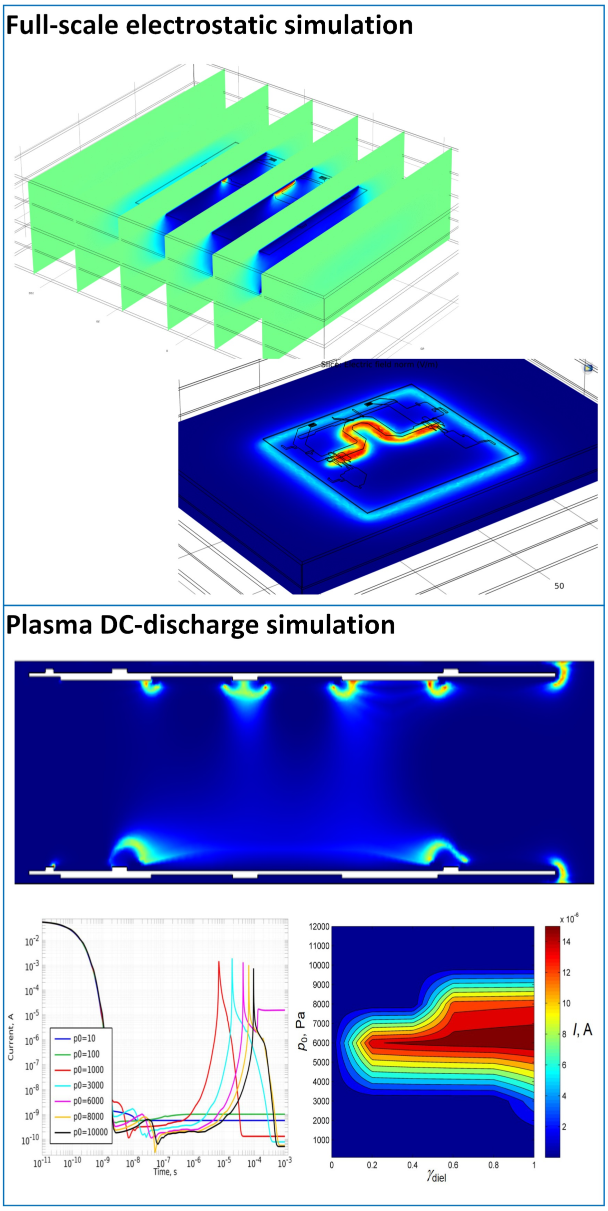
Full-scale electrostatic simulation
50
Plasma DC-discharge simulation
Current, A
p0=10
p0=100
p0=1000
p0=3000
p0=6000
p0=8000
p0=10000
Time, s
p_0, Pa
γ_{diel}
x 10^-6
I, A

Figure 3