Electric Discharge Module:
Printer Head Simulation

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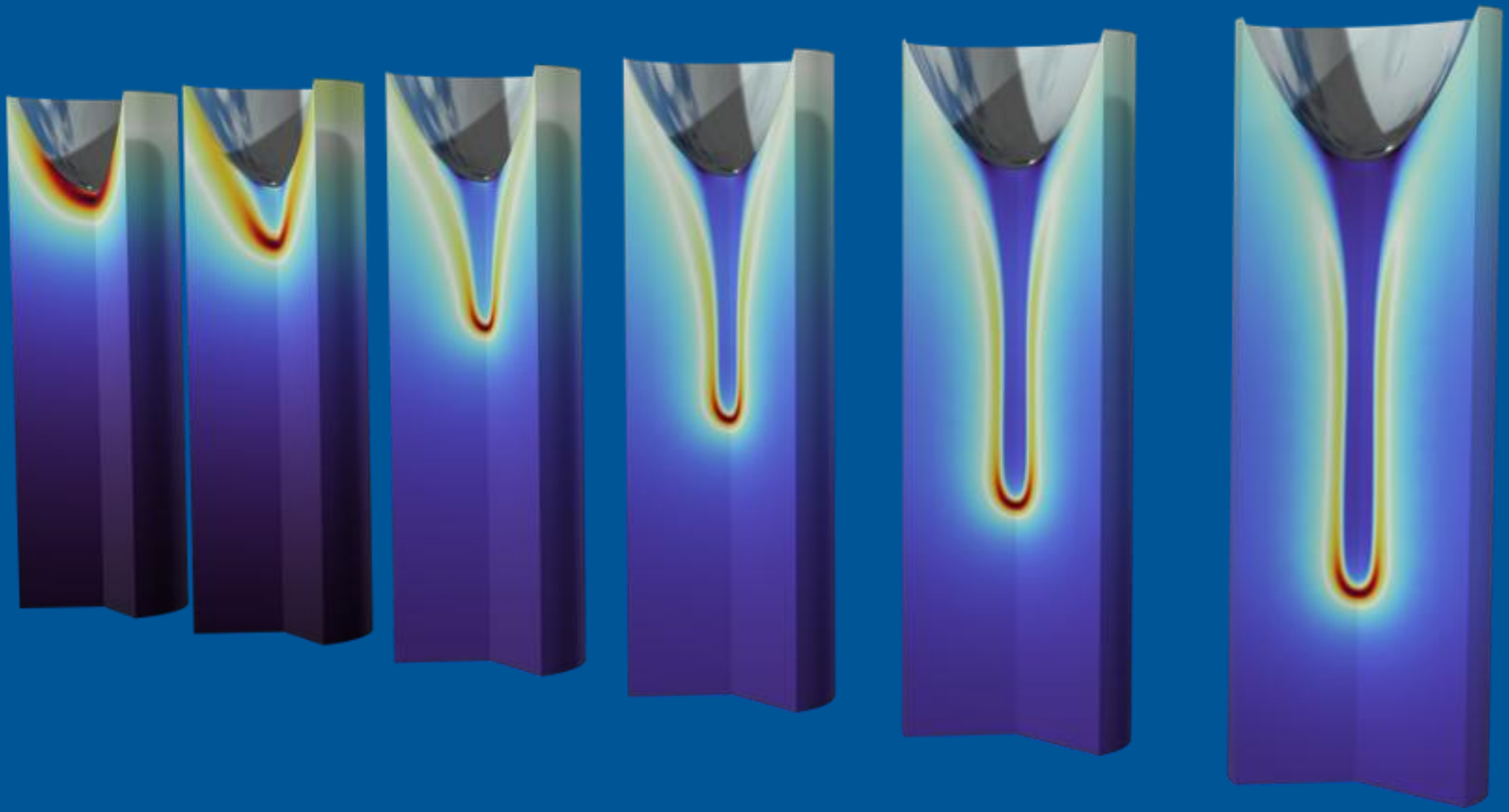

Electric Discharge Module

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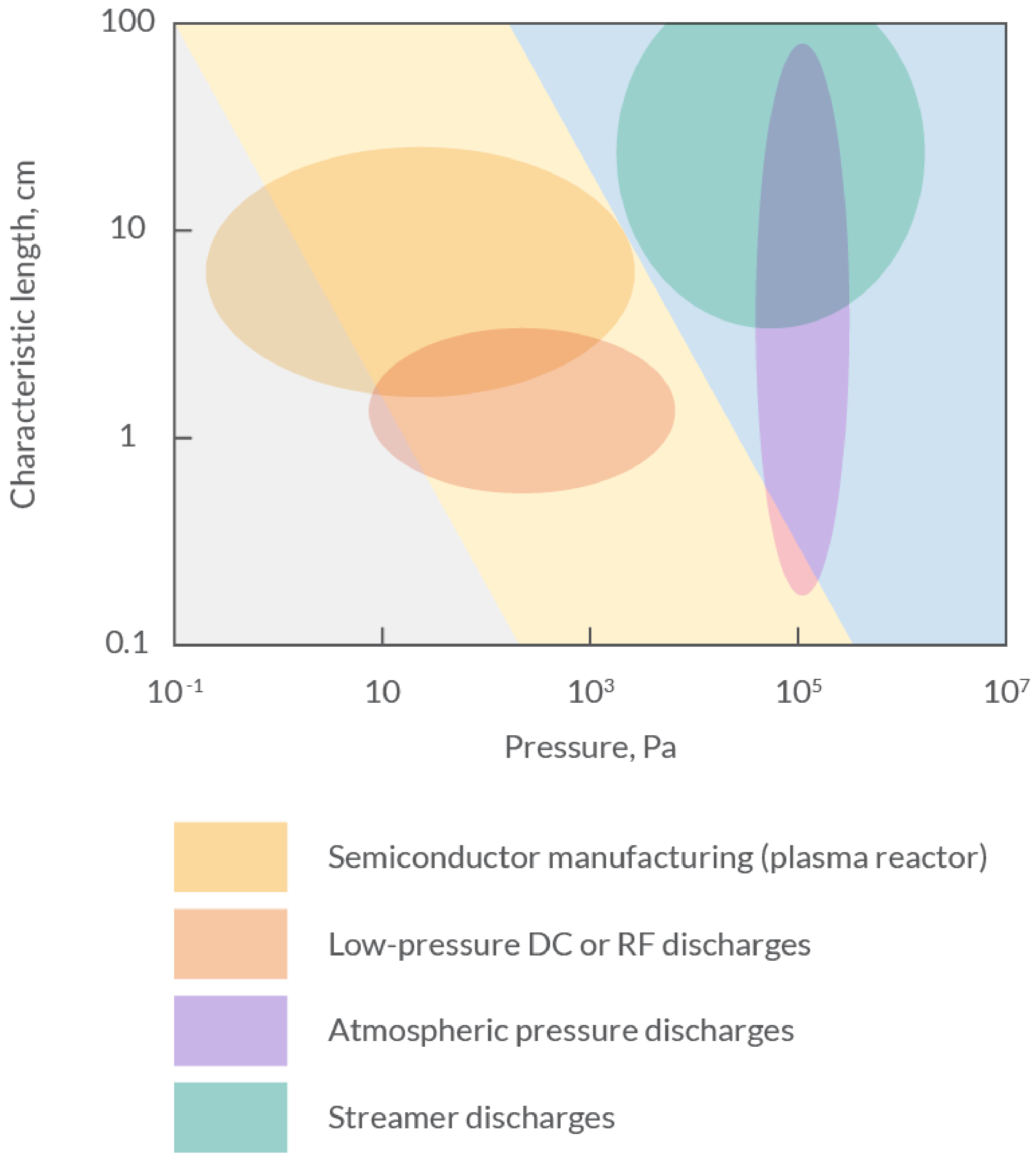
Electric Discharge Module or Plasma Module?

- The Electric Discharge Module is designed for atmospheric and high-pressure gas discharges, while the Plasma Module focuses on low-pressure gas discharges
- The Electric Discharge Module also enables simulations of discharge and charge transport in liquids and solids, unlike the Plasma Module, which is limited to plasma modeling in gases



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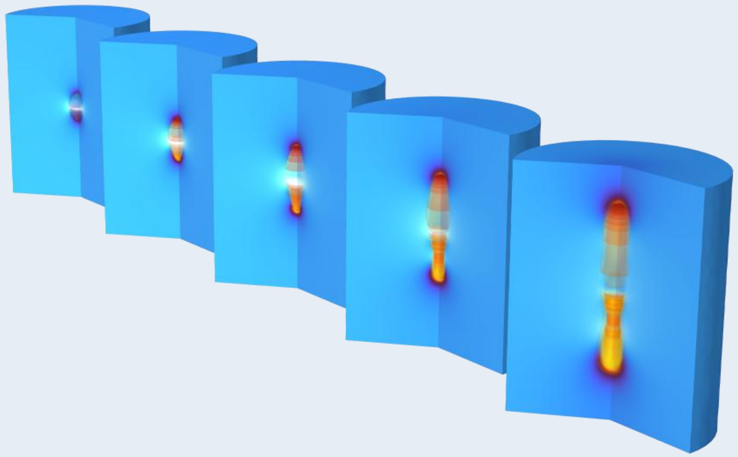
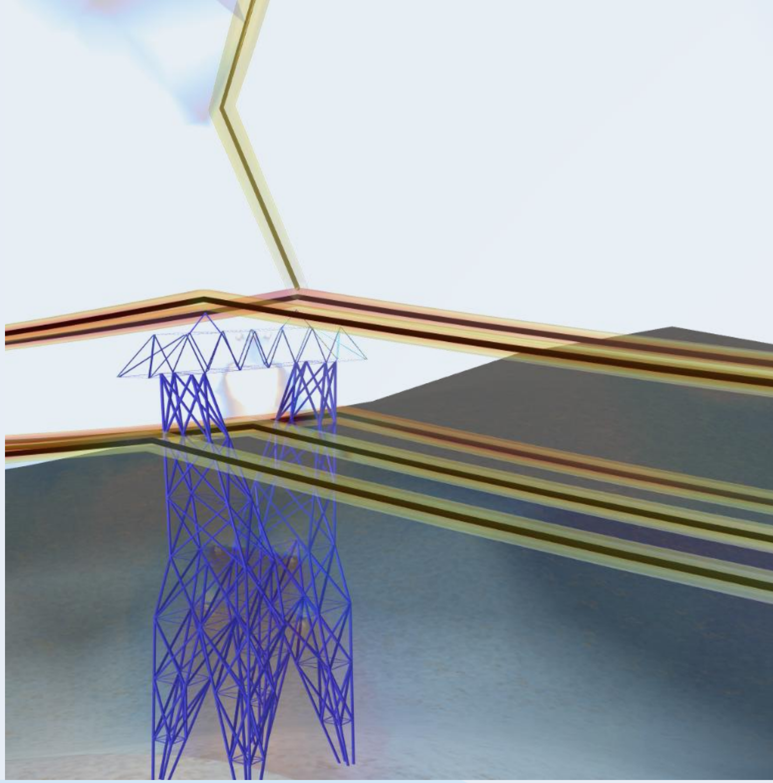
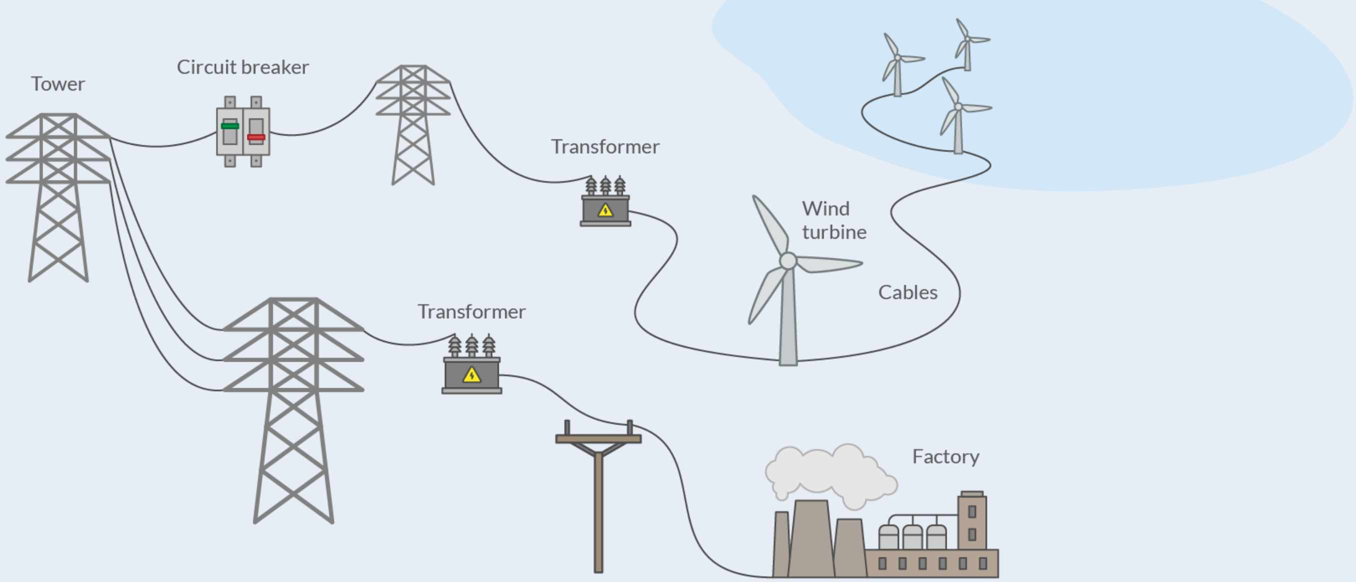
Electrical Insulation in Power Systems

- Internal insulation
  - Transformers
  - Circuit brakers
  - Cables
  - Gas-insulated switchgear (GIS)
- External Insulation
  - Insulators (overhead lines)
  - Bushings
  - Switching overvoltage
  - Lightning overvoltage

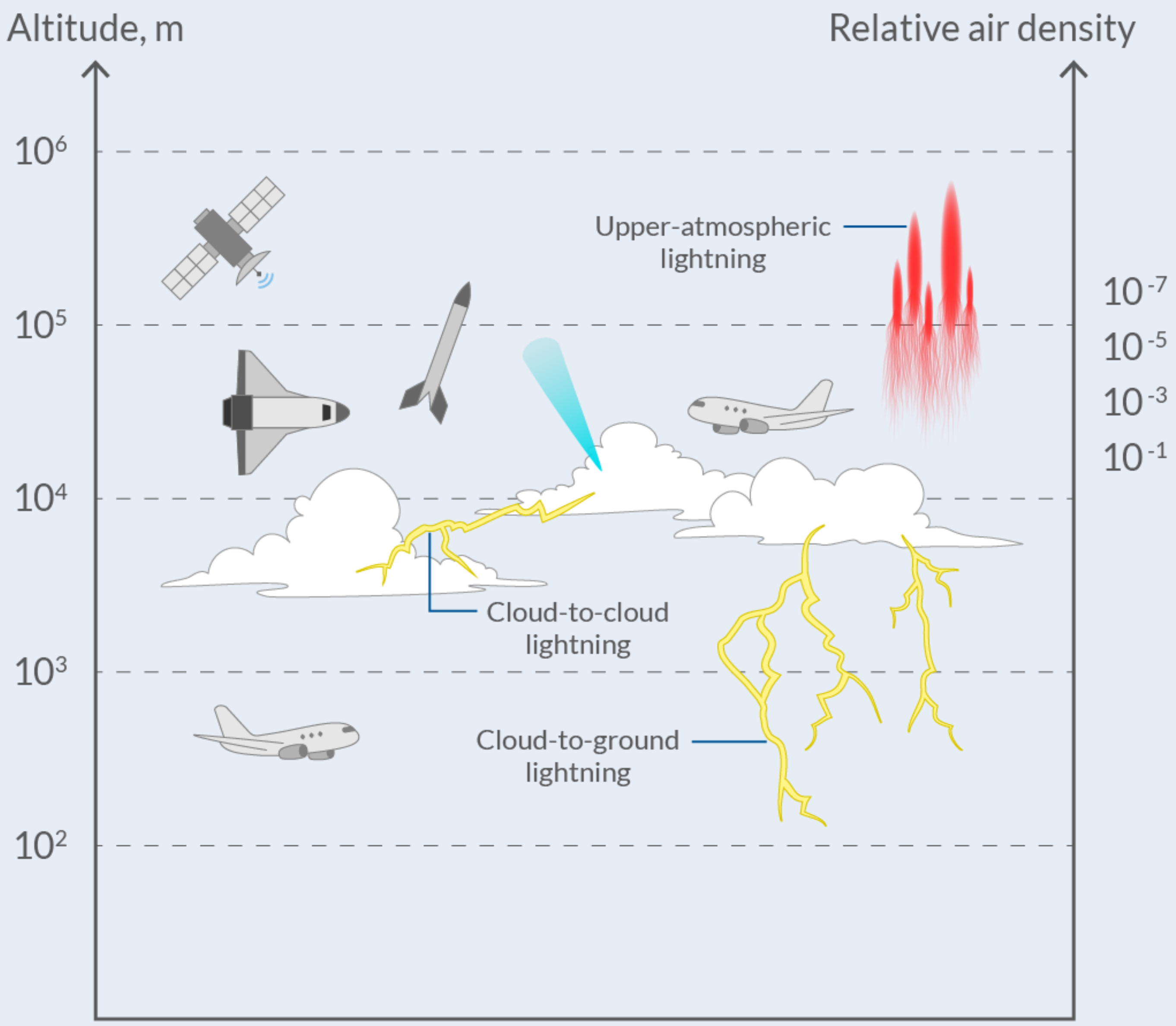






Electrical Insulation in Aerospace

- Aerospace vehicles are subject to a variety of electric discharges that can cause electrical insulation failure:
  - Internal discharge such as electric arcs
  - External discharge such as lightning
- The aerospace environment can be extreme, and the discharge is highly dependent on air pressure.
- Sustainable and clean energy drives greater use of composites, making electrical insulation more challenging.
- Simulation is an important tool for understanding and designing new insulation systems before experimentation.



Electric Discharge Processes

Charge

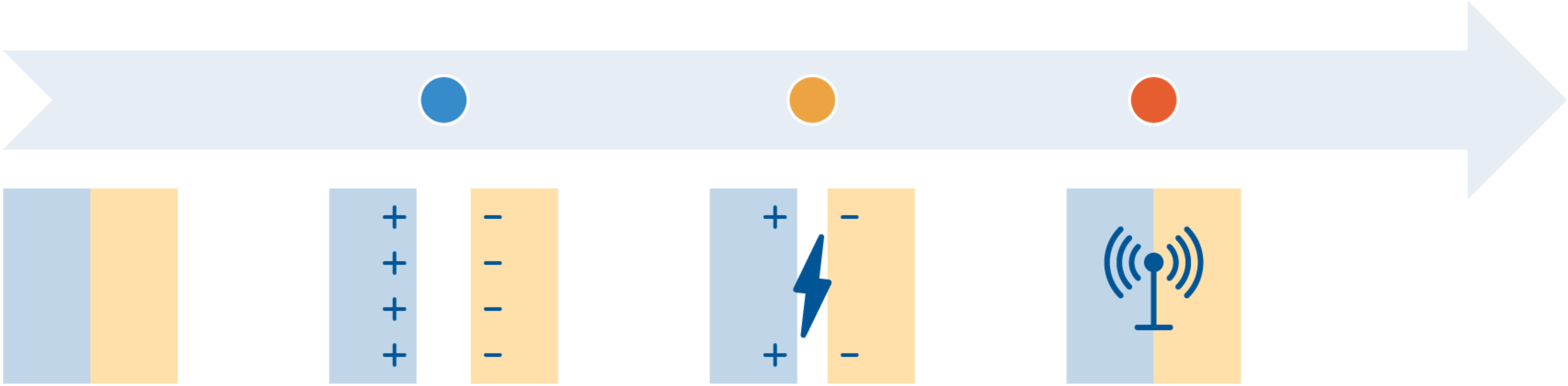
- Charge generation:
  - Charge separation
  - External charging
- Charge accumulation

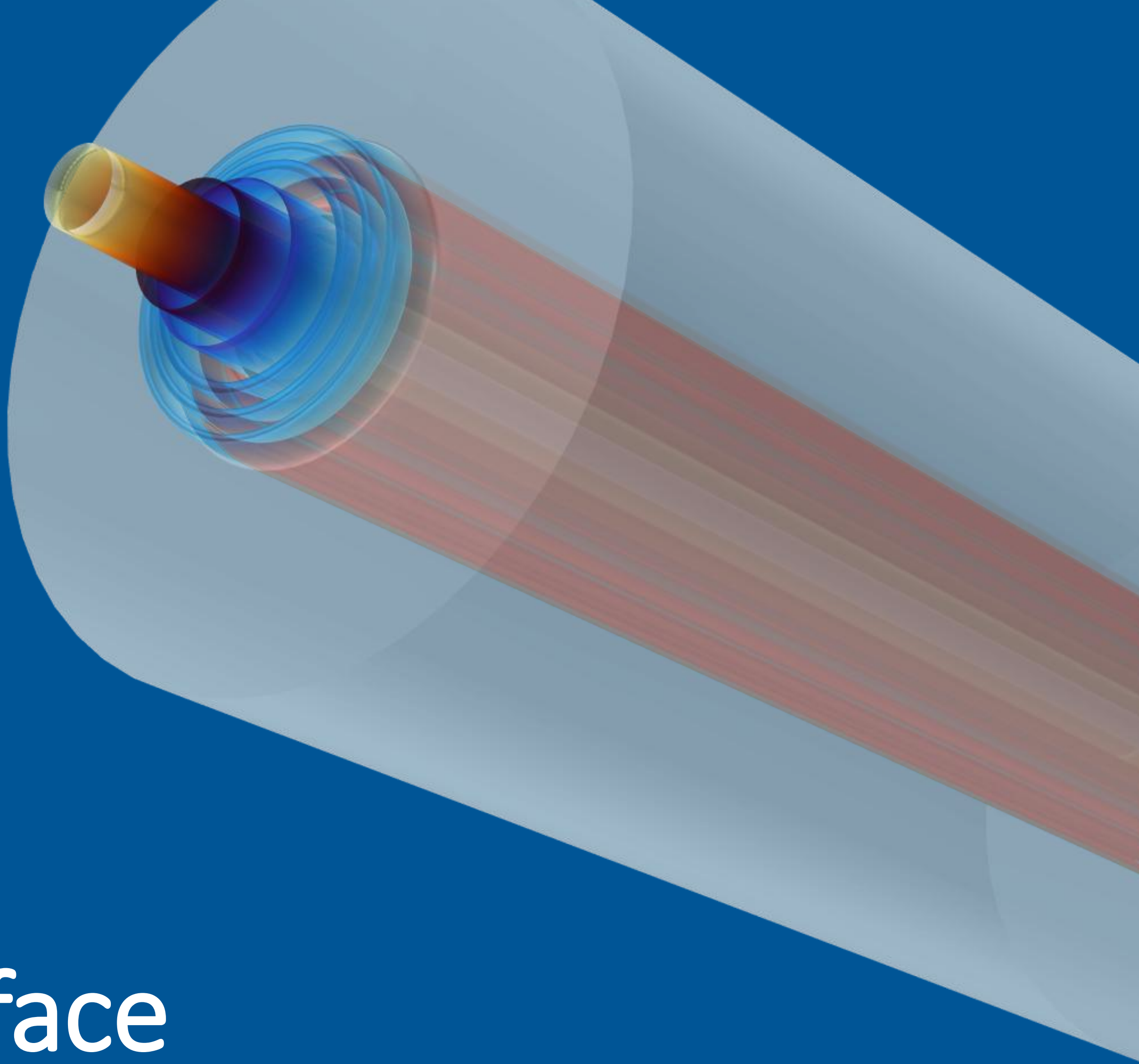
Discharge

- Charge relaxation
- Electric discharge:
  - Conductor–conductor
  - Insulator–conductor

After Discharge

- Direct effects
- Indirect effects:
  - Electric field coupling
  - Magnetic field coupling

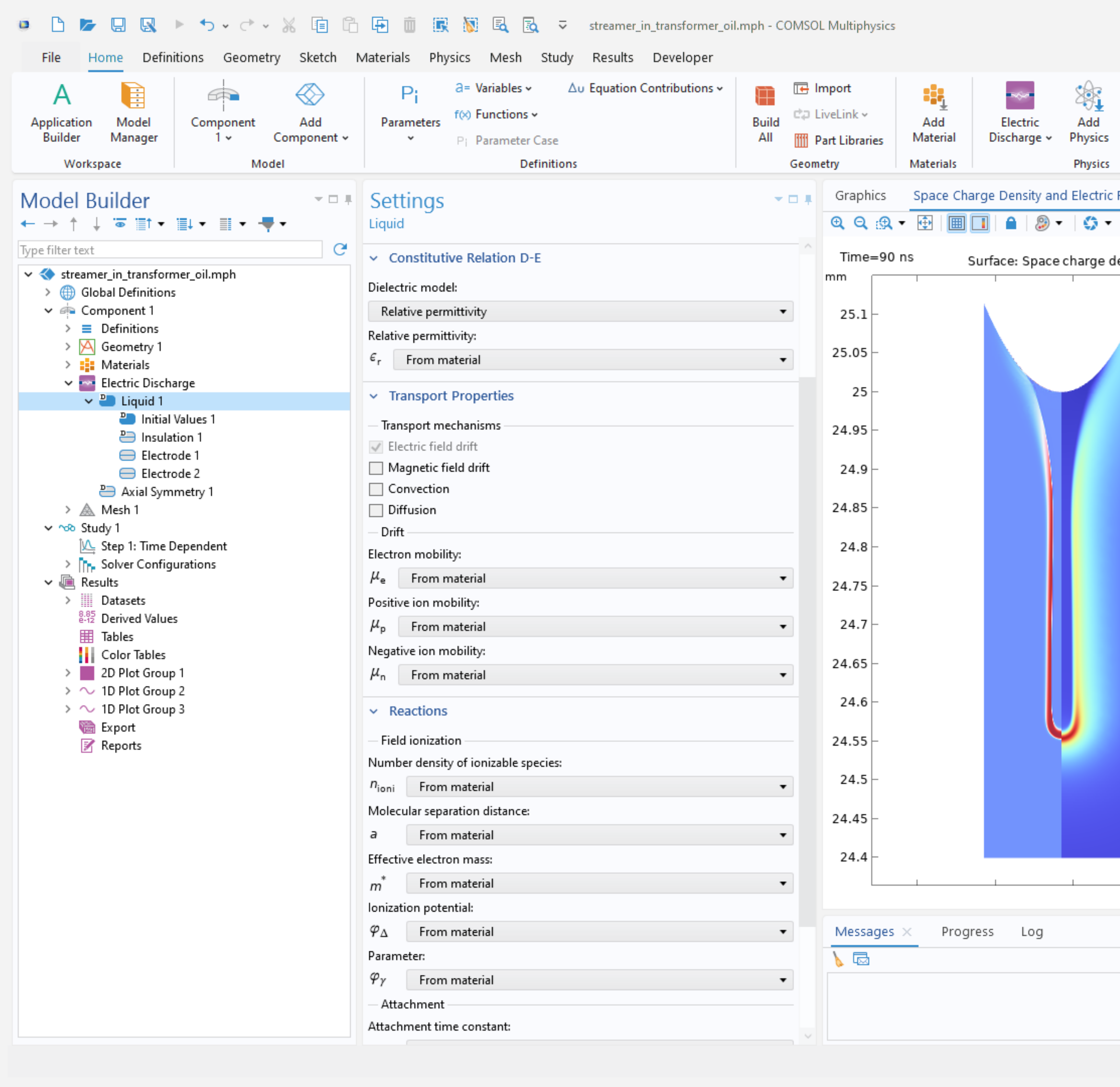


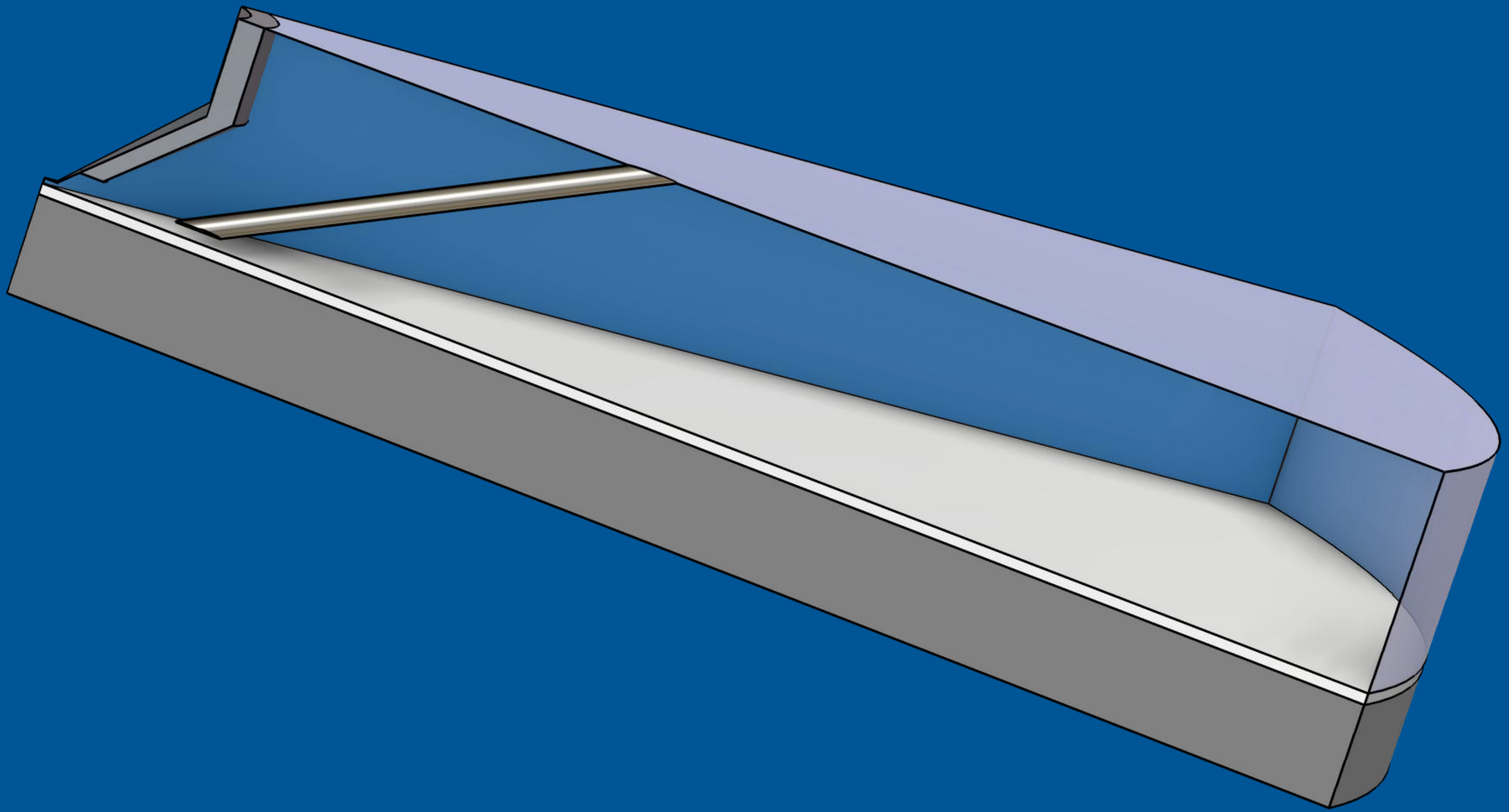


Electric Discharge Interface

Gas/Liquid/Dielectric Discharges

- Define your medium:
  - Model atmospheric and high-pressure gas discharges using fluid and local field approximations
  - Model liquid dielectrics, such as transformer oil
  - Model solid dielectrics, such as a polyethylene layer
- Solve transport equations for electrons, positive ions, and negative ions
- Incorporate processes like impact ionization, attachment, and recombination

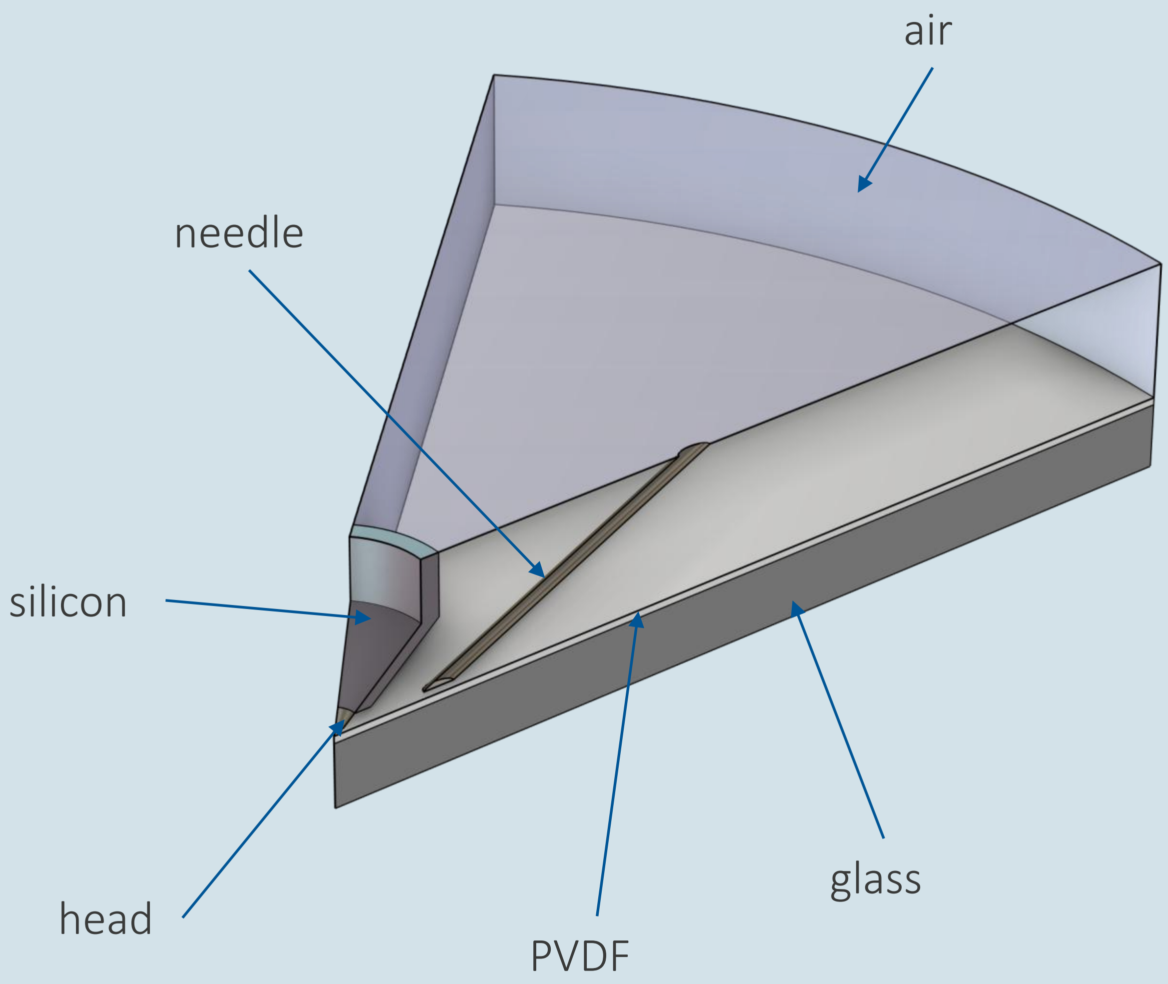




Printer Head Simulation

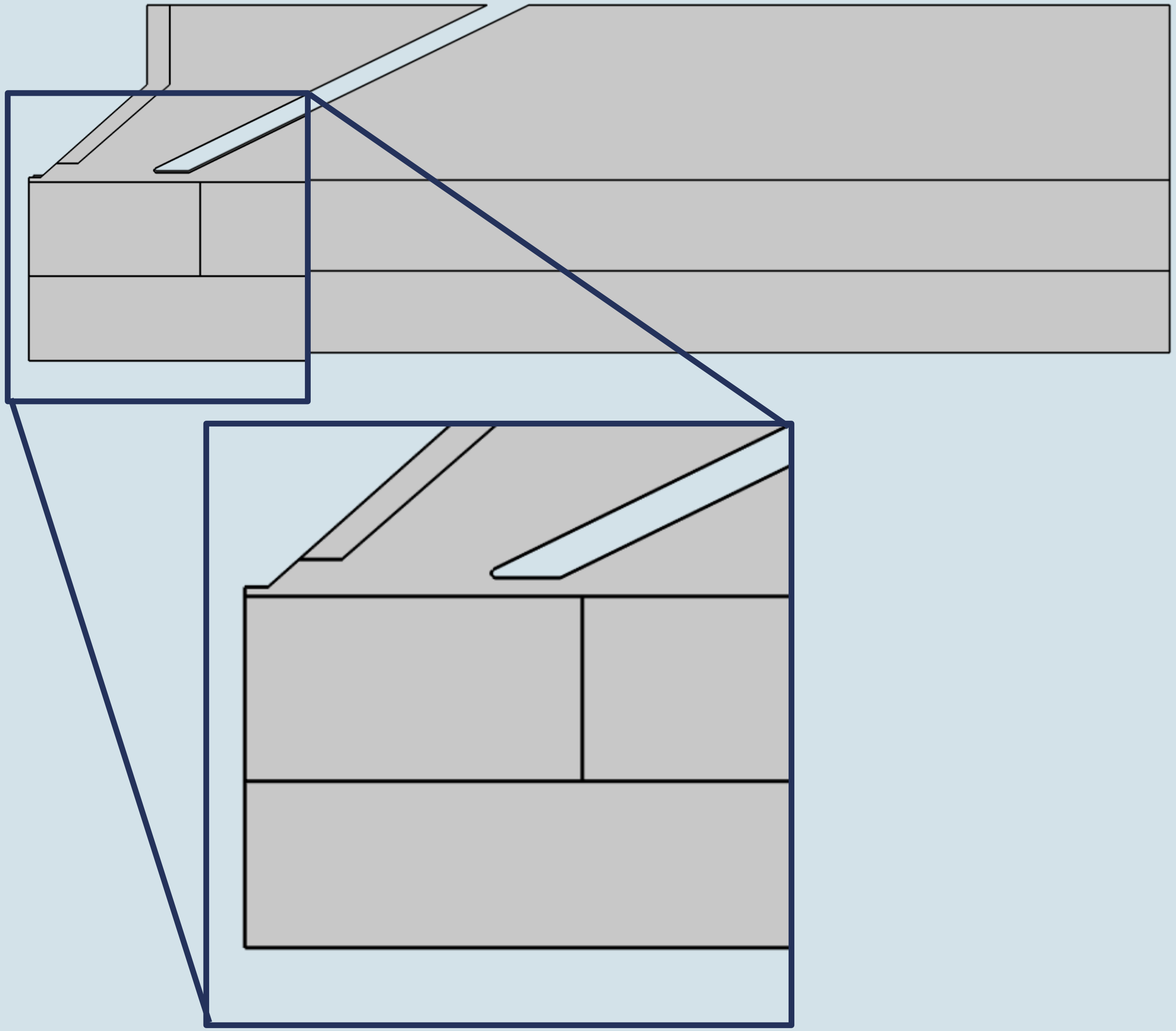
Adding The Space Charge Density

- Electrostatic base model substituted by Electric Discharge interface
  - Is there an influence of the space charge density?
- Challenges:
  - High mesh sensitivity
  - Finding the right initial potential value
- Setup tuning done in 2D

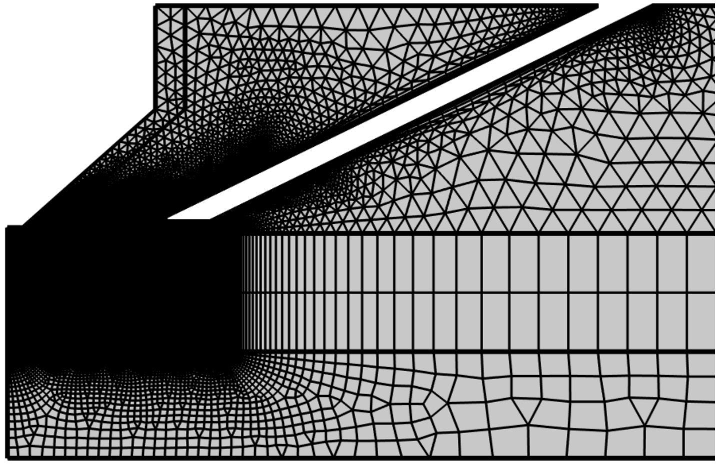


Model Adjustments

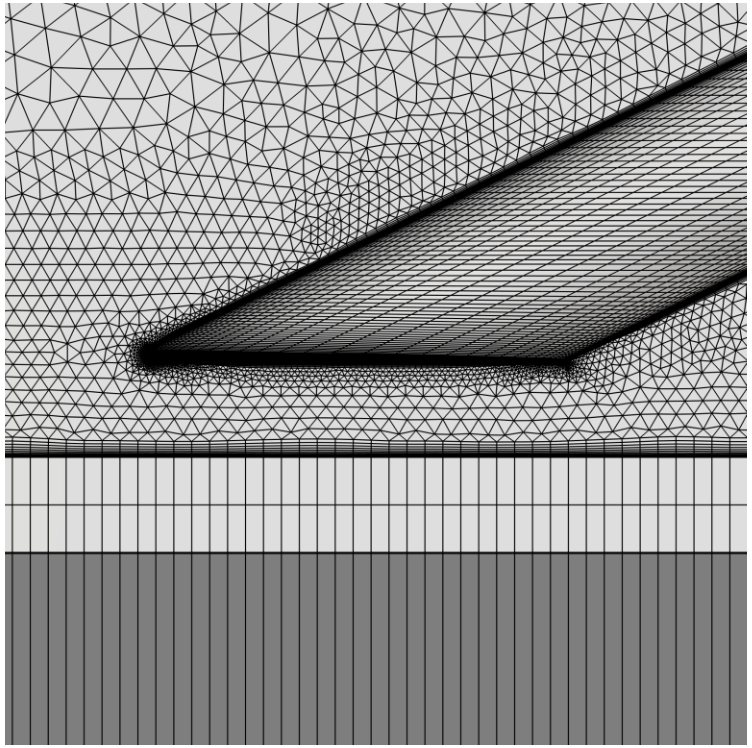
- Reducing the geometry radius
  - Verified geometry downsizing
  - Reduced computation time and increased stability
- Filleted needle tip
  - Removing the electric field singularity



Starting from 2D



2D: 134k DOF

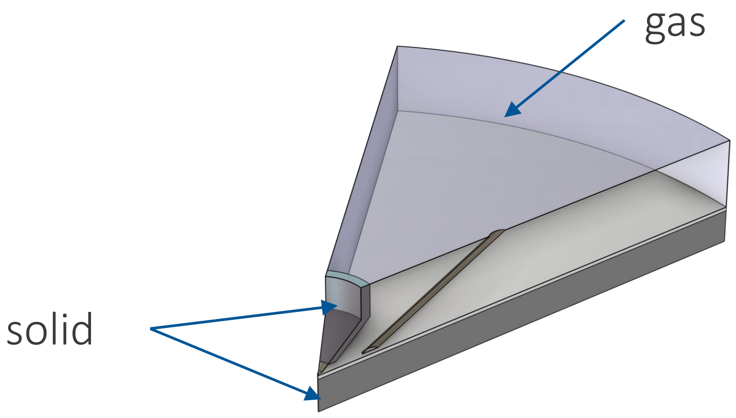


3D: 4000k DOF

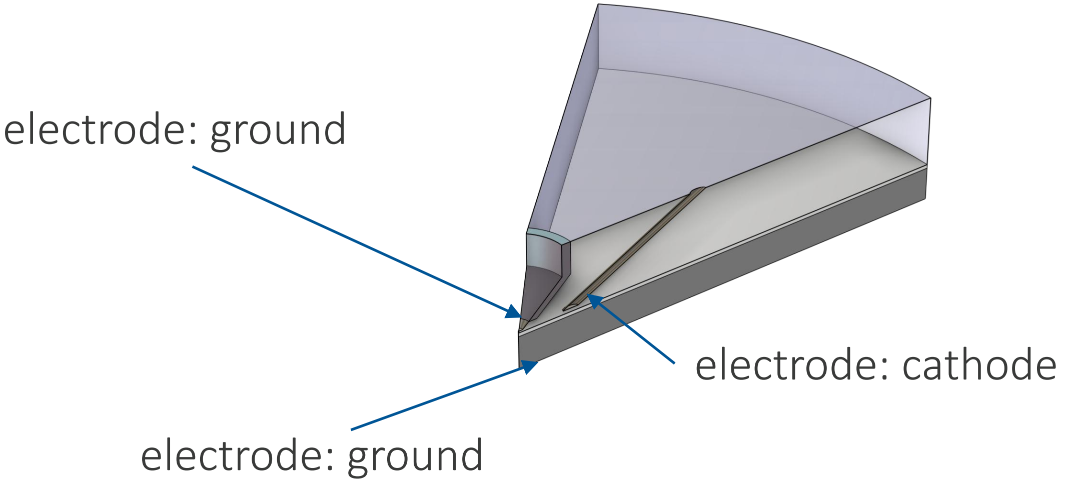
3D Model

- Solid medium doesn’t allow charge transport and ionization
- Gas medium does: Air [Kang et al. 2003]
- Electrodes
  - Ground: head and glass base
  - Cathode: needle

Domain conditions

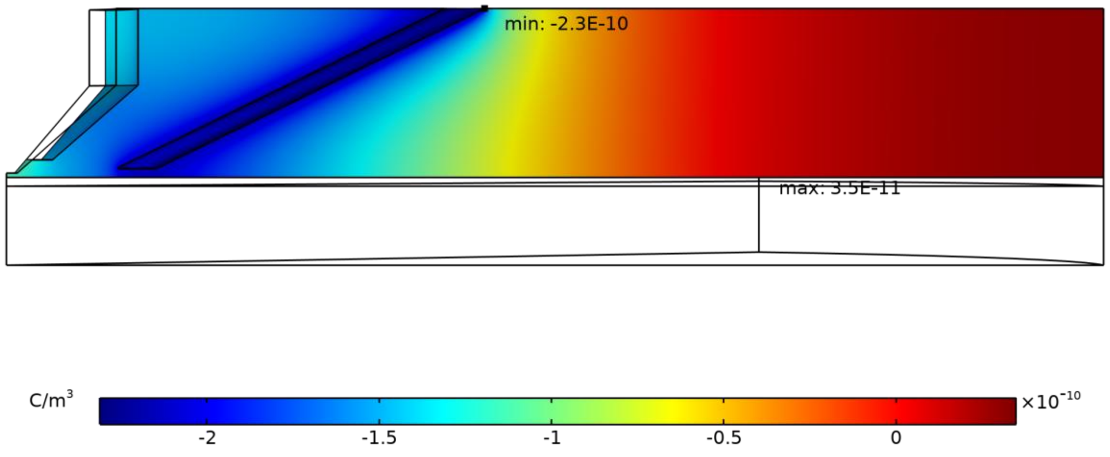


Boundary conditions

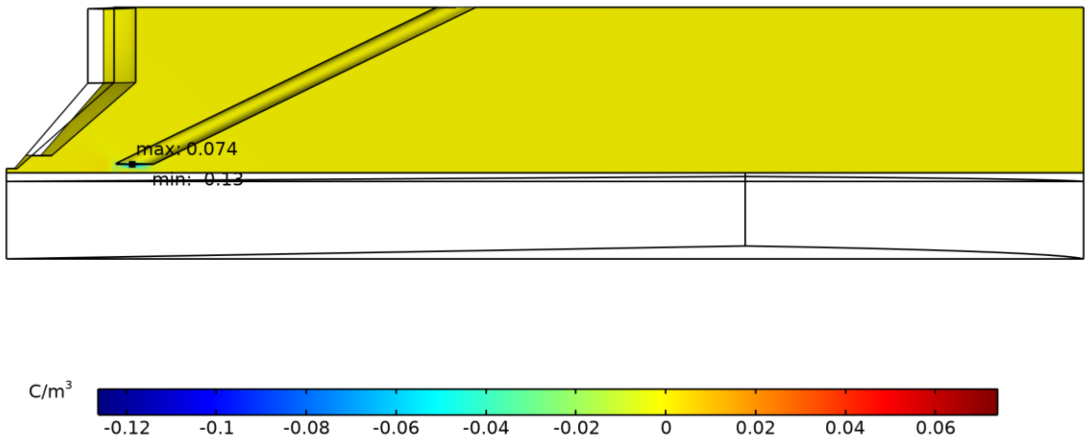


Space Charge Density Role

Initial step: 1E-3 V

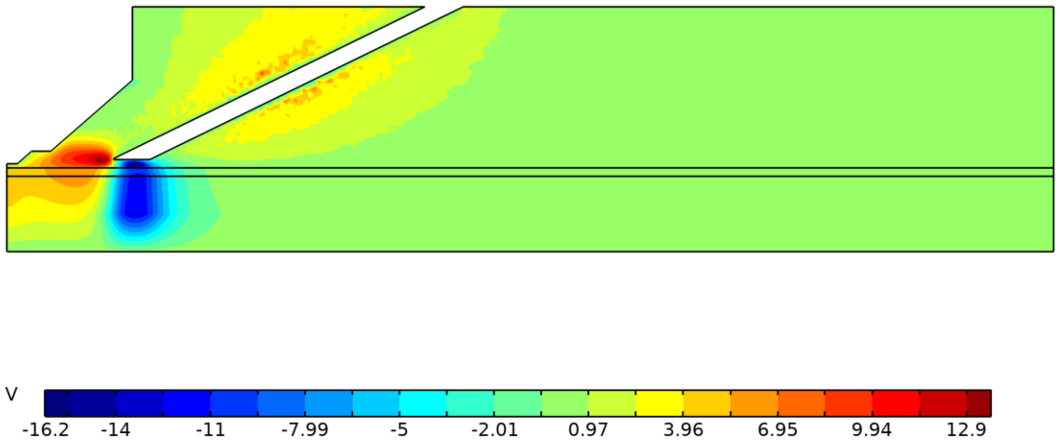


Final step: 1805 V



Electrostatics vs. Electric Discharge

Corona opening around: 1725 V



Final step: 1805 V