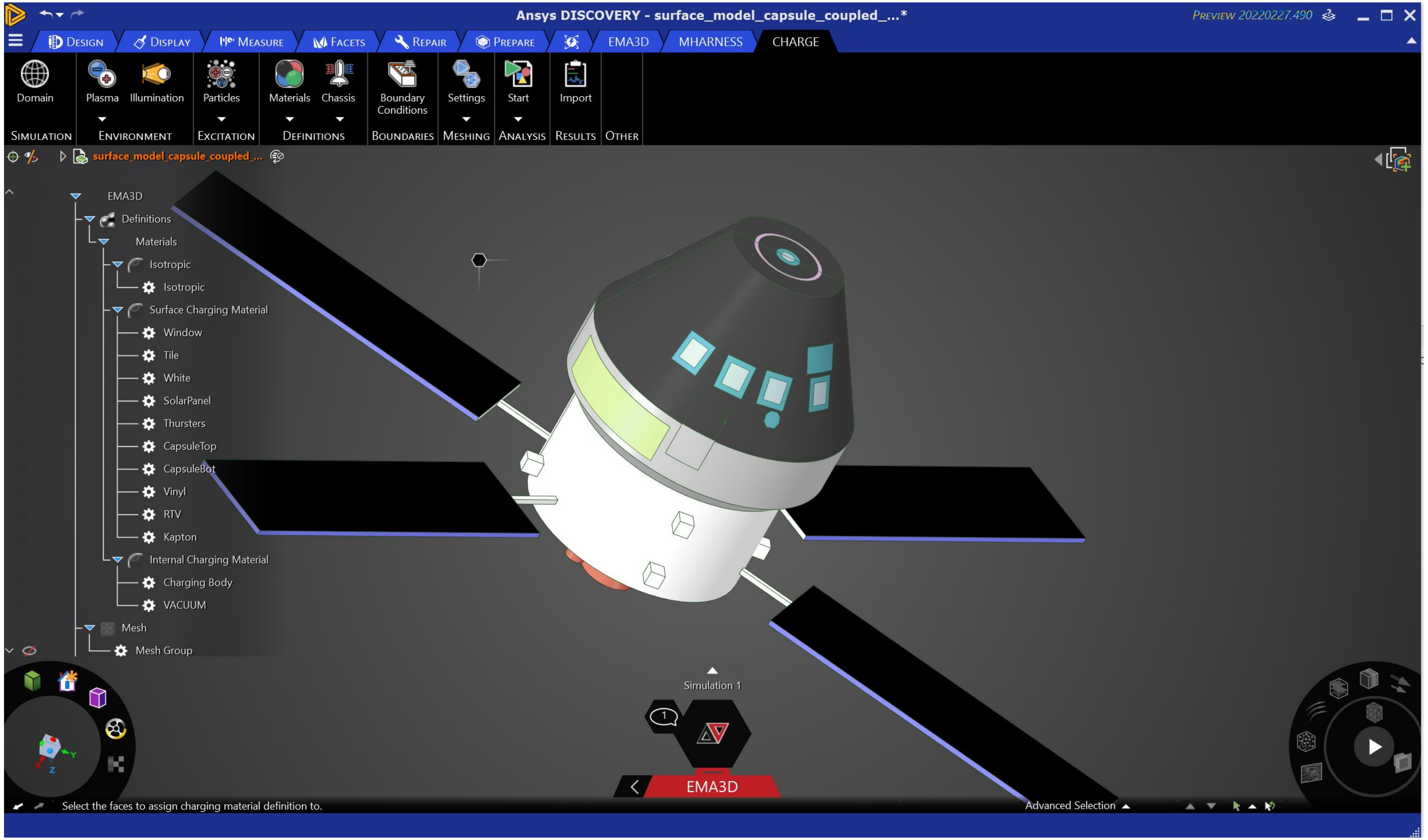
Ansys 2023 R1
Ansys EMA3D Charge Updates

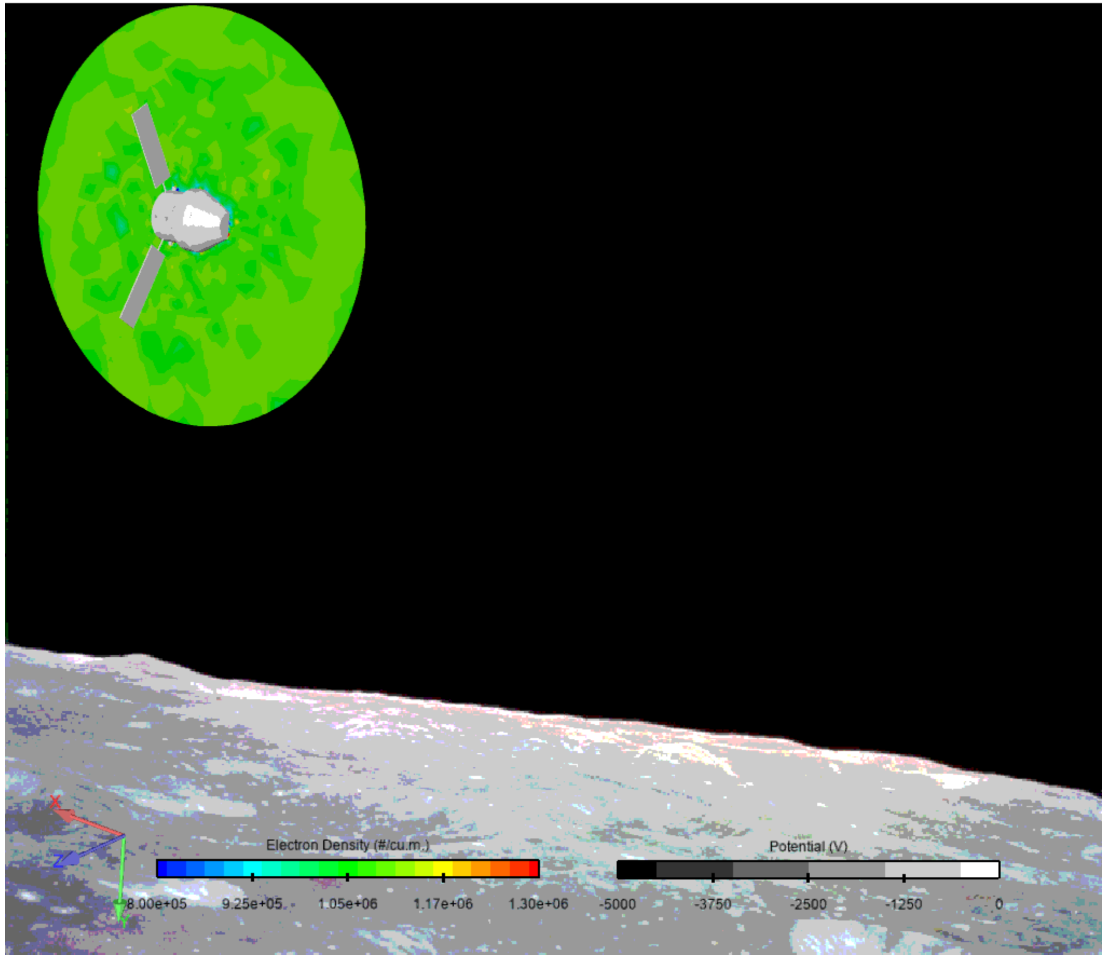
Ansys EMA3D Charge

Platform Level Charging and Discharging Solution



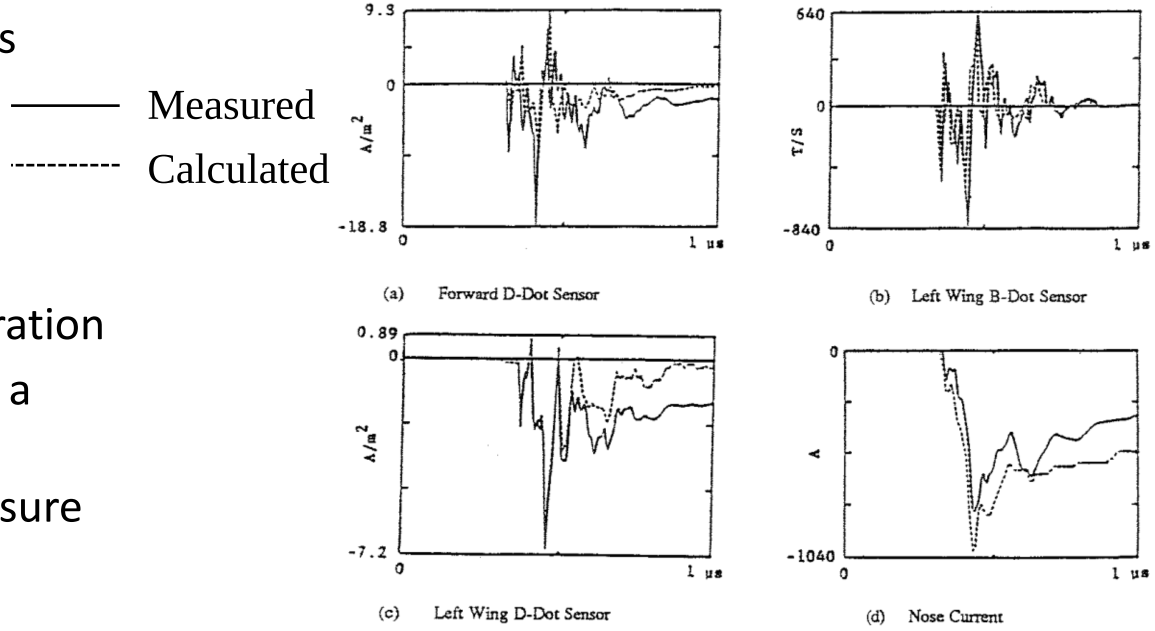
A Toolbox Fully Integrated into one Platform SpaceClaim

- 3D **Finite Difference Time Domain (FDTD)** method with non-linear air chemistry module
  - **Air ESDs**
- Matrix solution of **Surface Charge Balance** equations
  - **Surface Charging**
- Full-wave **Finite Element Method (FEM)**
  - **Internal Charging and Solid ESDs**
- **Monte Carlo (MC) Transport** of energetic particles interacting with bulk materials
  - **Charging and Radiation Hardening**
- **Particle-in-Cell** model to track low energy charge particles and collisions
  - **Dense plasmas**



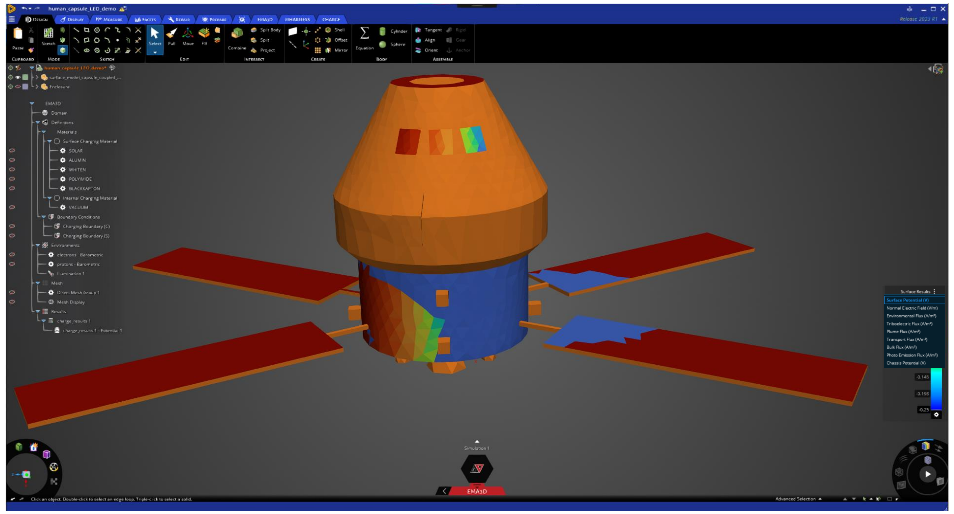
Ansys EMA3D Charge Distinguishing Features

- Accurate
  - Decades of validation heritage of experiment compared to simulation on complex platforms
  - Full wave solution of electromagnetic equations in FEM and FDTD
  - Non-linear air chemistry solution for arc formation in air
  - Stochastic tree model with particle transport for dielectric breakdown
  - 3D EM field and plasma calculations for surface charging physics
- Easy to use
  - User interface within Ansys Discovery
  - Intuitive for new users
  - Utilize mechanical CAD directly with minimal cleaning or preparation
  - Prepare models of complex platforms and material stack-ups in a fraction of the time of other methods
  - Easily change background properties such as humidity and pressure

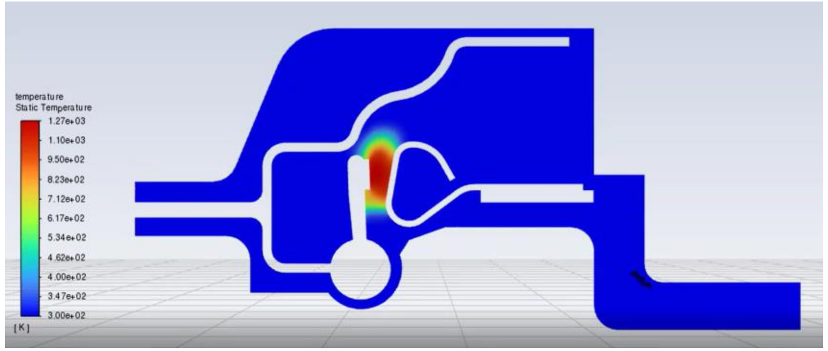


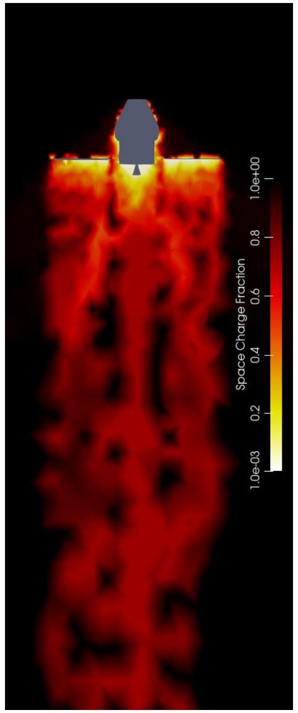
2023 R1 New Features – A Focus on Integration

- Integration with Discovery's Graphite (Data visualization) and Artemis (Mesh engine)



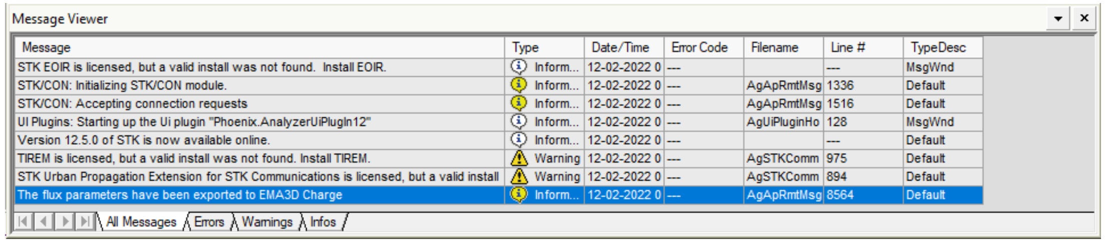
- Integration with System Coupling 2.0 for co-simulation with Fluent





- 3D analytical plasma models for quicker surface charging solutions in Interplanetary and LEO space environments

- Integration with Ansys STK

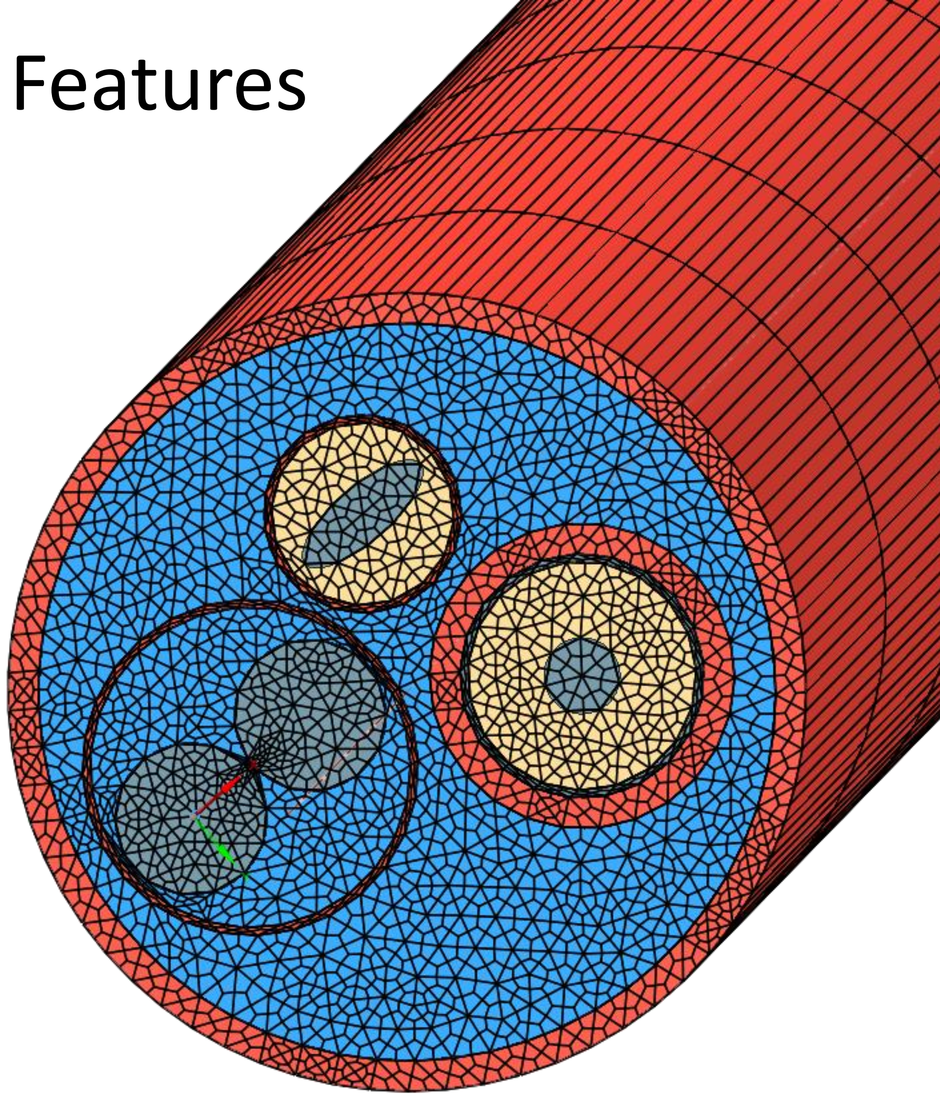

Message Viewer

Message	Type	Date/Time	Error Code	Filename	Line #	TypeDesc
STK EOIR is licensed, but a valid install was not found. Install EOIR.	Inform...	12-02-2022 0	---		---	MsgWnd
STK/CON: Initializing STK/CON module.	Inform...	12-02-2022 0	---	AgApRmtMsg	1336	Default
STK/CON: Accepting connection requests	Inform...	12-02-2022 0	---	AgApRmtMsg	1516	Default
UI Plugins: Starting up the Ui plugin "Phoenix.AnalyzerUiPlugIn12"	Inform...	12-02-2022 0	---	AgUiPluginHo	128	MsgWnd
Version 12.5.0 of STK is now available online.	Inform...	12-02-2022 0	---		---	Default
TIREM is licensed, but a valid install was not found. Install TIREM.	Warning	12-02-2022 0	---	AgSTKComm	975	Default
STK Urban Propagation Extension for STK Communications is licensed, but a valid install	Warning	12-02-2022 0	---	AgSTKComm	894	Default
The flux parameters have been exported to EMA3D Charge	Inform...	12-02-2022 0	---	AgApRmtMsg	8564	Default

All Messages / Errors / Warnings / Infos

2022 R2 Ansys EMA3D Charge - Additional Features

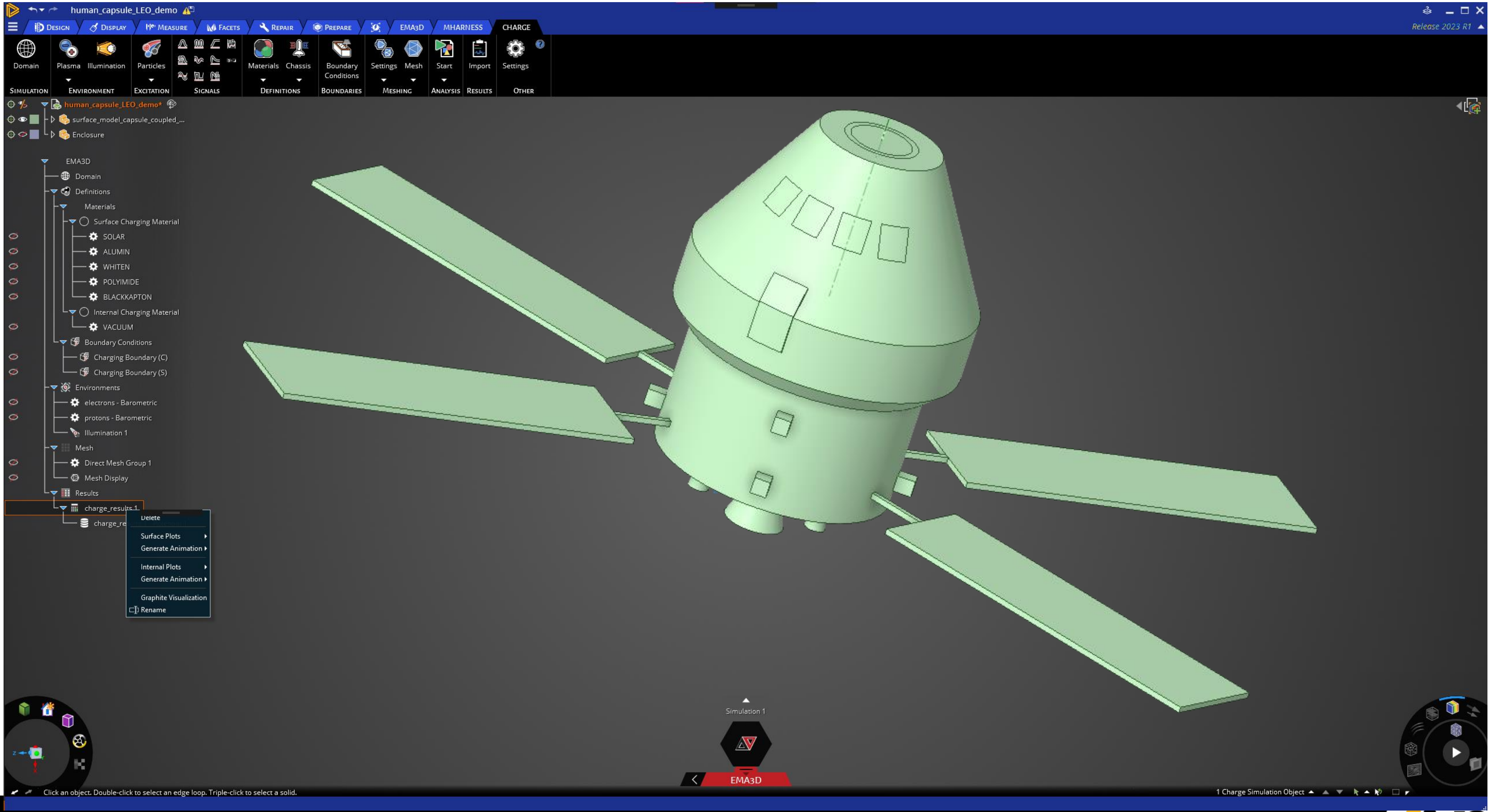
- Integral Flux input window for Particle Transport
- New boundary conditions for FEM
  - Conductive
  - E-field components
- New sources for FEM – Current
- Source time varying plasma densities for PIC
- Ion source for Particle Transport
- Total non-ionizing dose (TNID) calculations
- Air breakdown switch
- New Mesh Engine: Artemis (beta)
- User Experience improvements such as tool reorganization
- Updated Transport Code + physics package choice
- FEM parallelization switched to Intel MPI
- Extrusions are back and improved!
- Time varying plasma parameters are back!



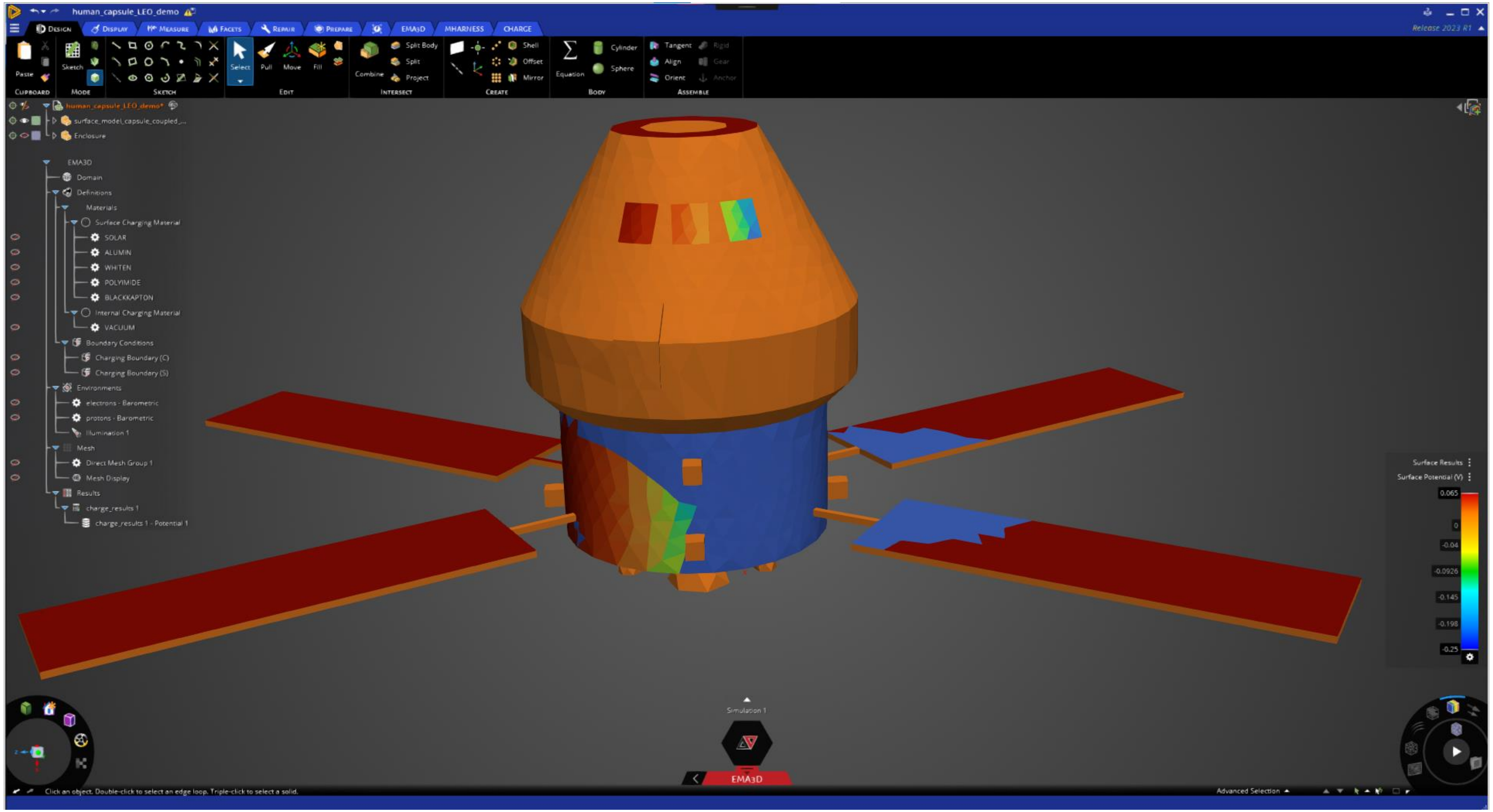
Highlight Feature: Integration with Ansys Discovery's Graphite (Visual) and Artemis (Mesh)

Ansys

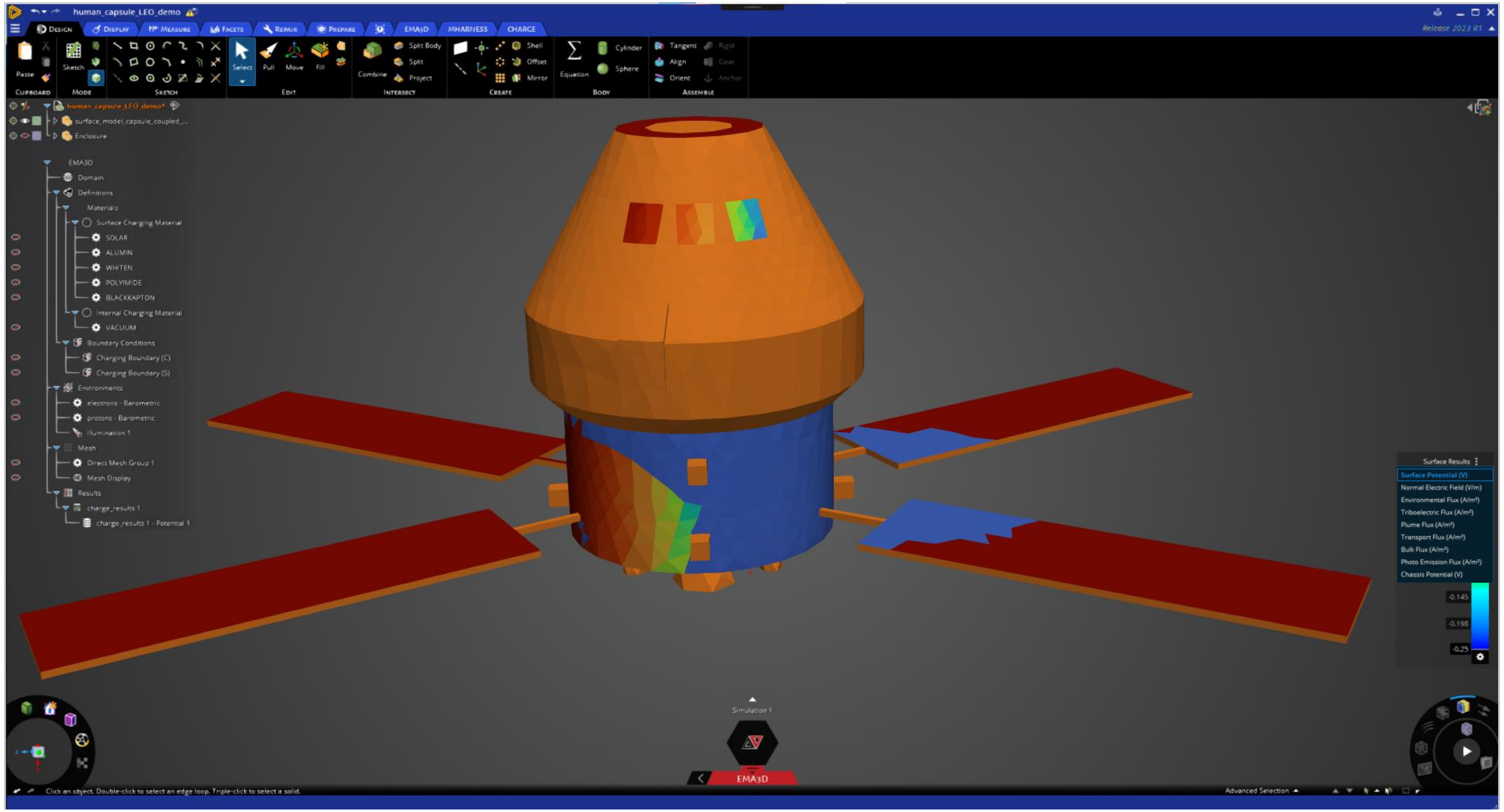
Access Graphite Visualization from the Simulation Tree

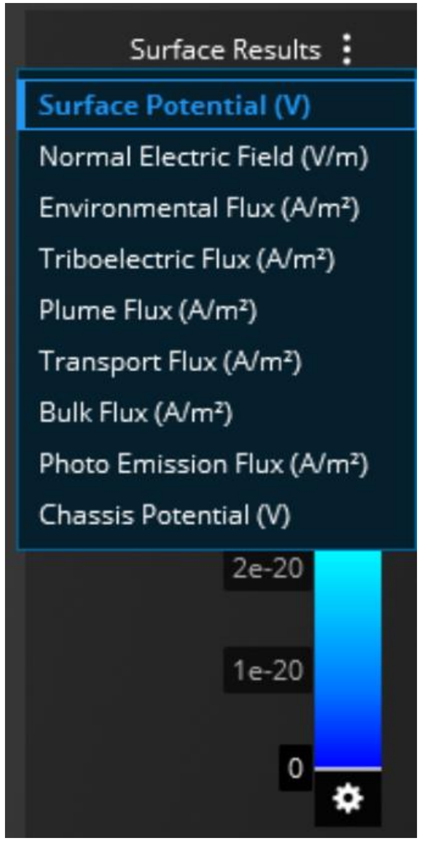


Change Color Scale Ranges, and Hover Elements for More Details

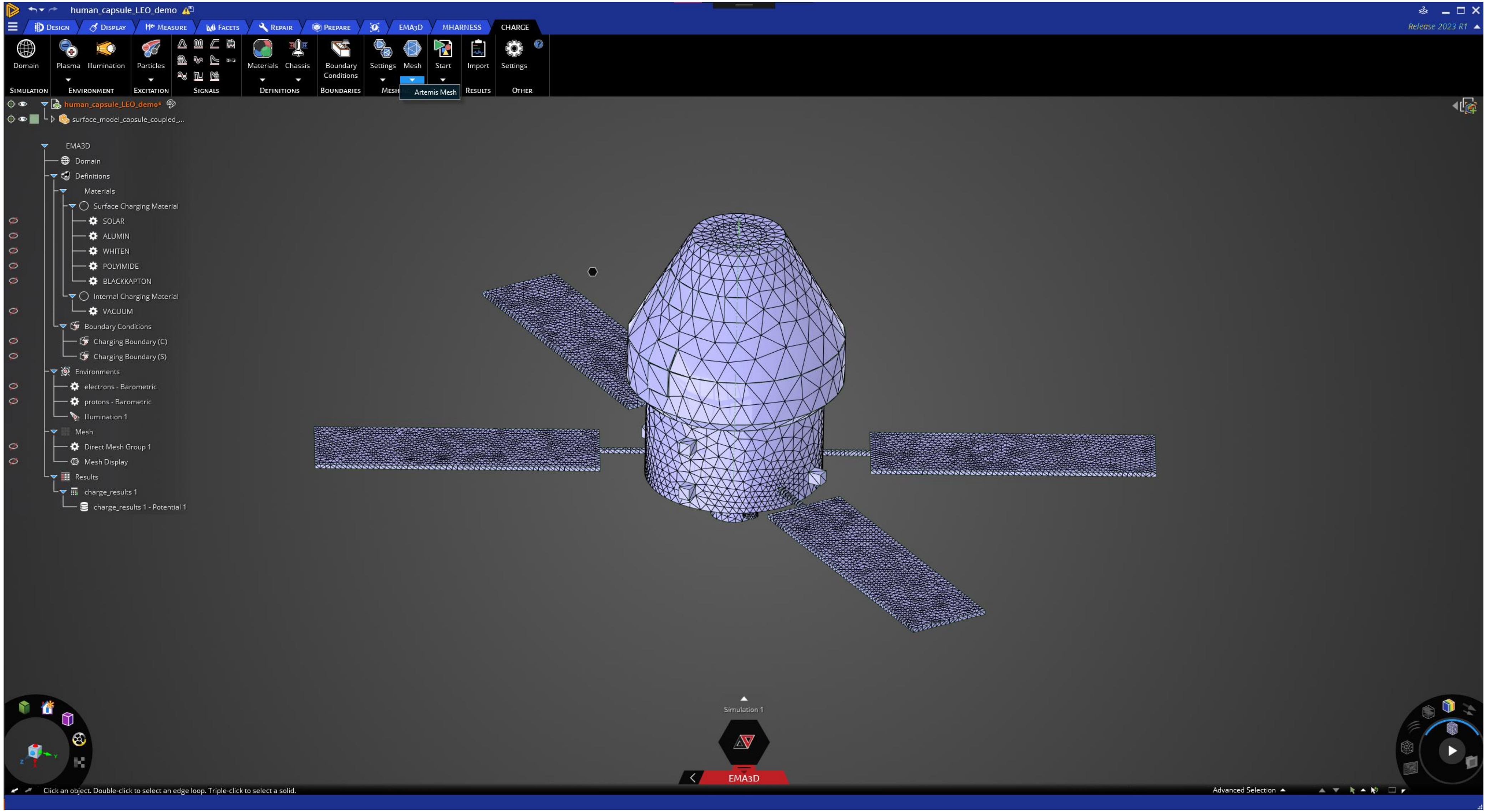


Quickly Shift between Variables





Use the Artemis Mesh Engine for Quicker, Reliable Meshing



EMA3D User Interface includes Ansys Discovery

- New Graphite visualization enables quick data visualization for result analysis
- Hovering on the geometry provides values of elements in specific location
- Easily switch between variables and time steps

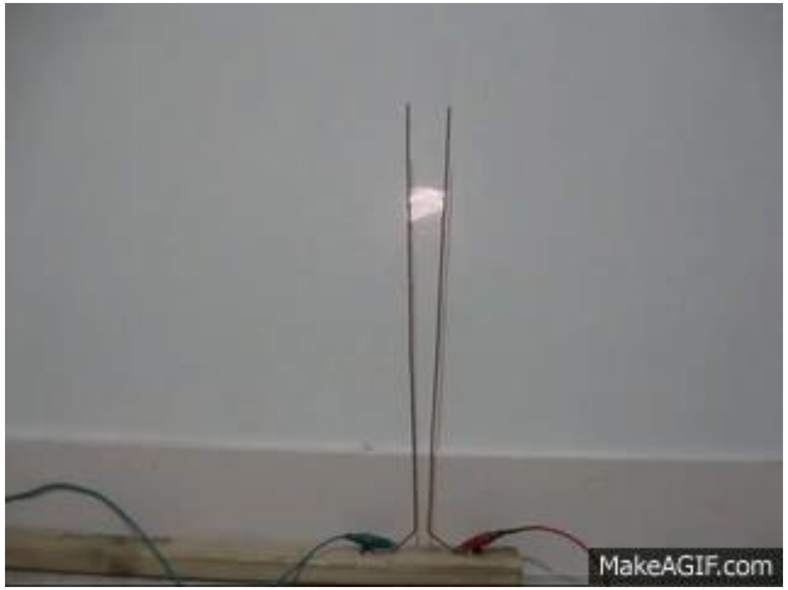
- New Artemis meshing is >10x faster, more robust and more reliable
- All capabilities for mesh groups (local fidelity) are retained

Highlight Feature: Coupling EMA3D Charge to Ansys Fluent

Ansys

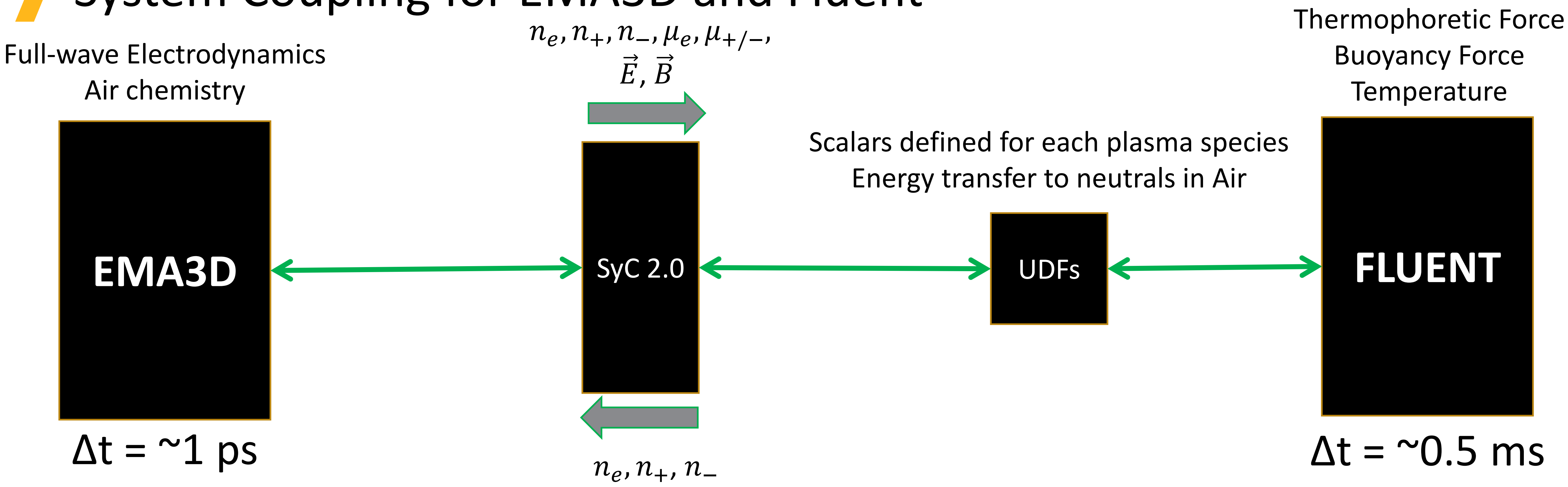
System Coupling for EMA3D Charge and Fluent

- EMA3D Charge models air ionization and recombination, hence it can model arc creation and dissipation.
- However, to model arc propagation, thermodynamics and longer time scales are required.
- By co-simulating between Fluent and EMA3D Charge, we can tackle this multi-physics phenomena.
- System Coupling 2.0 allows for co-simulation of two very different solvers, optimized for their own physics on respective time step sizes



We can see from Jacob's ladder that buoyancy of hot air makes the arc move up. When upside down, the magnetic forces are not enough to make the arc move.

System Coupling for EMA3D and Fluent



<u>Possible workflow:</u>

1. EMA3D Charge simulates 50 ns with a time step of 1 ps to generate the arc,
2. Arc is sent to Fluent UDF through SyC2.0 and UDF is used to calculate energy transferred to neutrals,
3. Fluent simulates 10 ms with a time step of 0.5 ms,
4. At each time step, Fluent calls EMA3D Charge for 50 ns to update electrodynamics and particle densities.

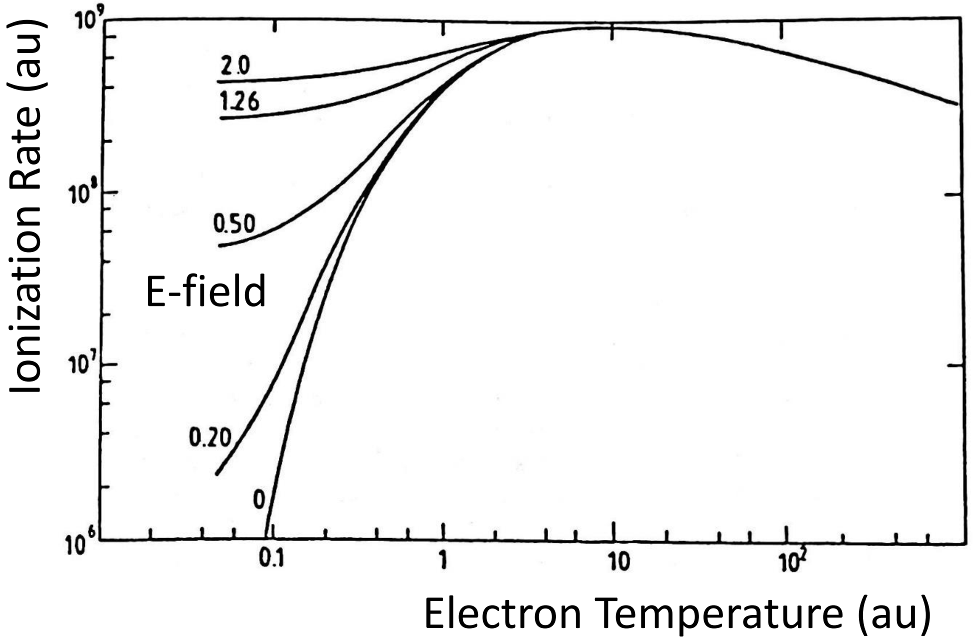
*Only steps 1 and 2 are needed to know Temperature generated by arc generation.

System Coupling for EMA3D and Fluent – Step 1 – Arc generation

Non-linear chemistry for arcing in air leveraged from EMA's knowledge of corona formation.

We use fluid conservation equations:
T. Rudolph and R. A. Perala, "Development and Application of Linear and Nonlinear Methods for Interpretation of Lightning Strikes to In-Flight Aircraft," *NASA CR-3974,* 1986.

Accurate representation of the generation of charge carriers.



Energy conservation:

$$\frac{\partial \epsilon_e}{\partial t} + (\vec{v_e} \cdot \nabla)\epsilon_e = q_e n_e \vec{E} \cdot \vec{v_e} - \frac{m_e}{n_H}\nu_c(\epsilon_e - \epsilon_e^0) + g n_e\left(\frac{1}{2}m_e v_+^2 - \epsilon_{ion}\right) + \epsilon_Q - \alpha_e\epsilon_e - \beta n_+\epsilon_e + H_e - k_{excitation}$$

$$\frac{\partial \epsilon_H}{\partial t} + (\vec{v_+} \cdot \nabla)\epsilon_H = q_+(n_+ + n_-)\vec{E} \cdot \vec{v_+} - \frac{m_e}{n_H}\nu_c(\epsilon_e - \epsilon_e^0) - \frac{1}{2}g n_e m_e v_+^2 + k_{excitation}$$

Particle density conservation:

$$\frac{\partial n_e}{\partial t} + \nabla \cdot (n_e\vec{v_e}) = Q + g n_e - \alpha_e n_e - \beta n_e n_+ + k_e$$

$$\frac{\partial n_+}{\partial t} + \nabla \cdot (n_+\vec{v_+}) = Q + g n_e - \beta n_e n_+ + k_e - \gamma n_+ n_-$$

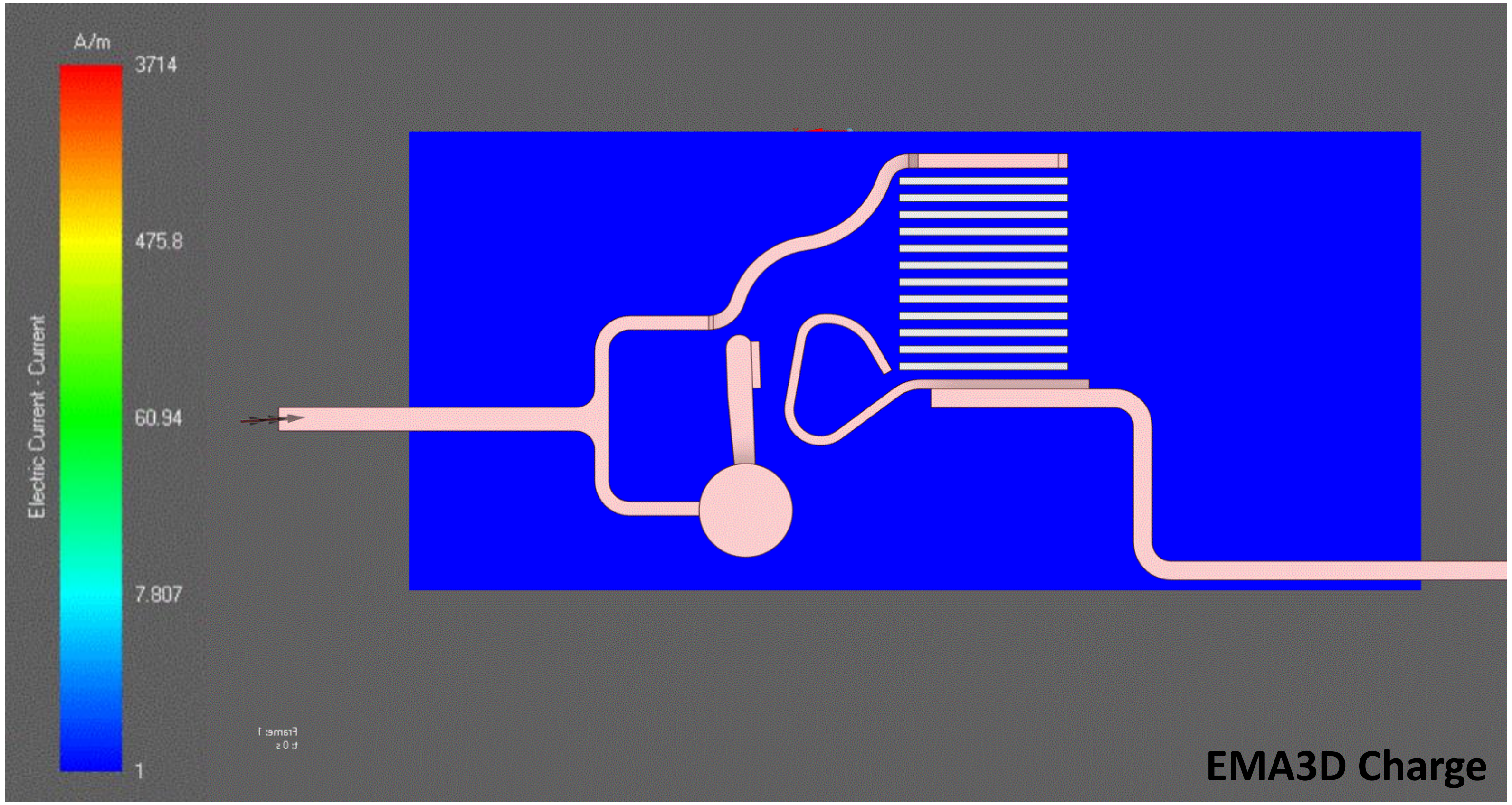
$$\frac{\partial n_-}{\partial t} + \nabla \cdot (n_-\vec{v_-}) = \alpha_e n_e - \gamma n_+ n_-$$

Momentum conservation:

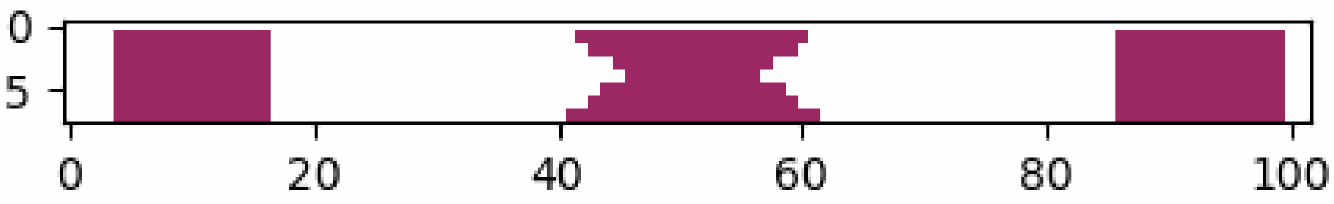
$$m_\alpha n_\alpha\left(\frac{\partial \vec{v_\alpha}}{\partial t} + (\vec{v_\alpha} \cdot \nabla)\vec{v_\alpha} + v_\alpha \nu_c\right) = n_\alpha q_\alpha\left(\boldsymbol{\vec{E}} + \frac{\mathbf{1}}{\boldsymbol{c}}(\boldsymbol{\vec{v_\alpha}} \times \boldsymbol{\vec{B}})\right) - \nabla p_\alpha$$

System Coupling for EMA3D and Fluent – Step 1 – 50 ns

- Material properties, non-linear air chemistry region, current density sources are all defined in EMA3D Charge,
- Inductance of the whole geometry plays a role in the arcing formation.

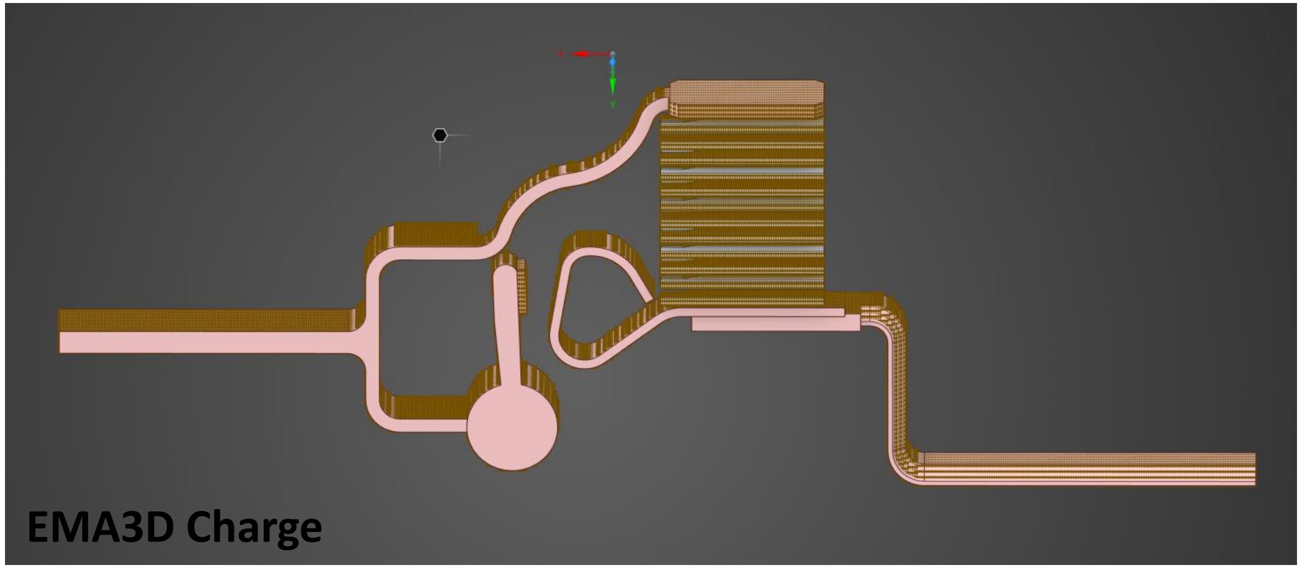


EMA3D Charge geometry may be moved by changing the target at every coupling time steps.



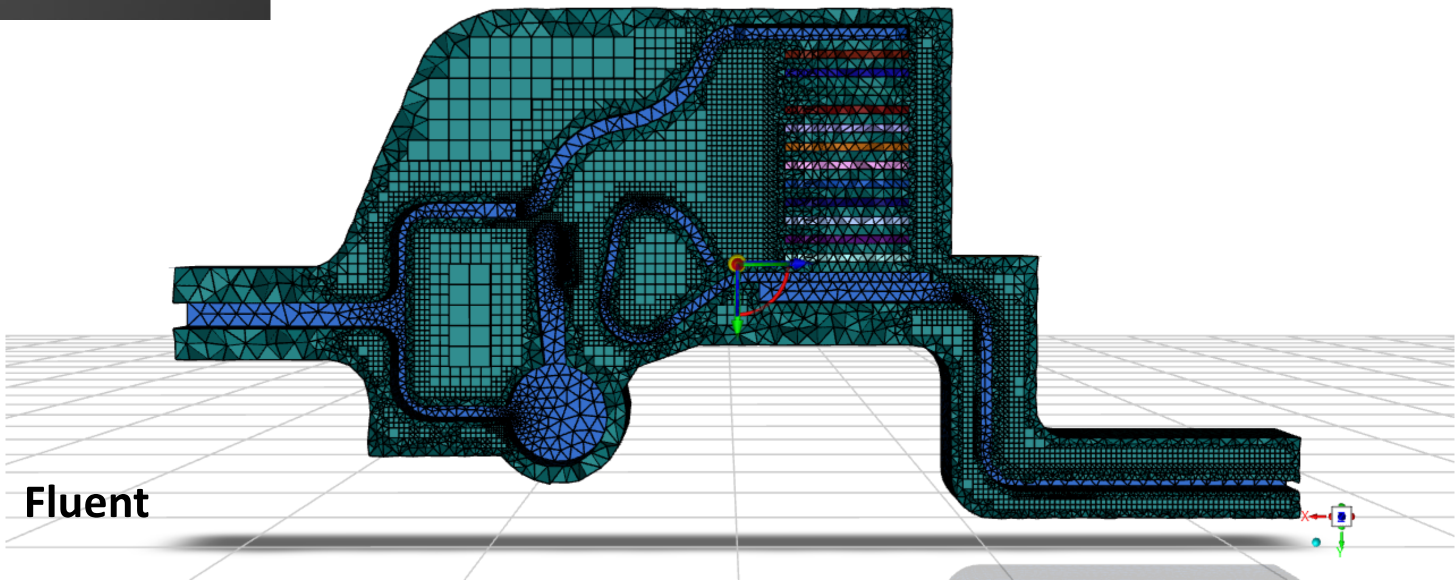
System Coupling for EMA3D and Fluent – Step 2 – SyC 2.0

- Coupling regions are defined in both solvers and System Coupling can map those two regions to one another even when meshes are relatively different.
- Coupling time steps is chosen in SyC 2.0 interface and the standardized UDFs are available with EMA3D Charge.



MAPPING SUMMARY

	Source	Target
Interface-1		
electric_field_in		
Mapped Volume [%]	92	>99
Mapped Elements [%]	92	>99
Mapped Nodes [%]	75	>99
electron_density_in		
Mapped Volume [%]	92	>99
Mapped Elements [%]	92	>99
Mapped Nodes [%]	75	>99
electron_mobility_in		
Mapped Volume [%]	92	>99
Mapped Elements [%]	92	>99
Mapped Nodes [%]	75	>99
ion_mobility_in		
Mapped Volume [%]	92	>99
Mapped Elements [%]	92	>99
Mapped Nodes [%]	75	>99
negative_ion_density_in		
Mapped Volume [%]	92	>99
Mapped Elements [%]	92	>99
Mapped Nodes [%]	75	>99
positive_ion_density_in		
Mapped Volume [%]	92	>99
Mapped Elements [%]	92	>99
Mapped Nodes [%]	75	>99



System Coupling for EMA3D and Fluent – Step 2 – the UDF

The total energy deposited into the neutrals is:

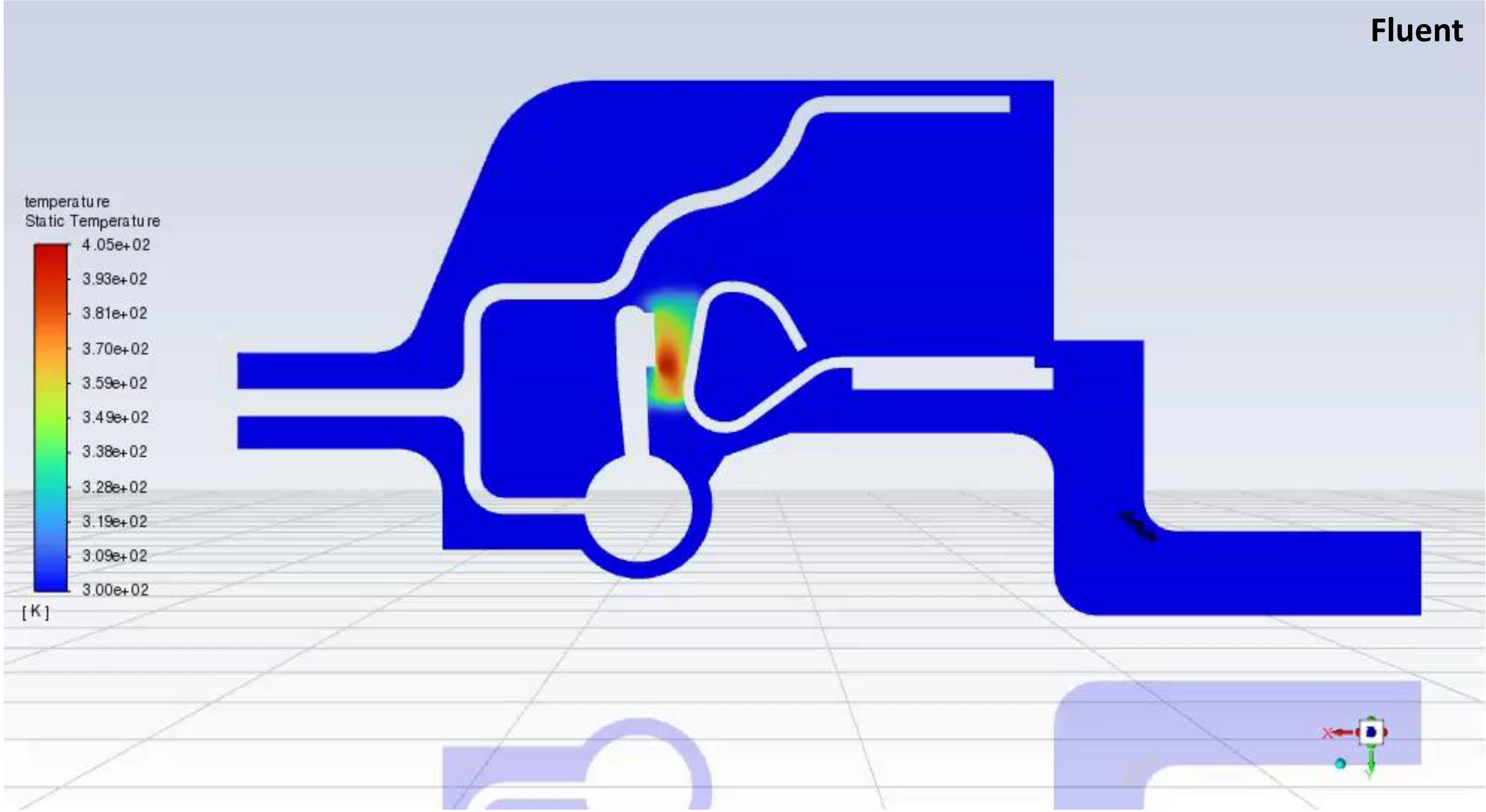
$$\Delta KE_{total} = \frac{1}{2}\sum_i \frac{q_i n_i}{m_i \mu_i} m_n (v_2^2 - v_1^2)$$

Where ΔKE_i is the energy deposited by the ith plasma species, $N_{col,i}$ is the number of collisions that occur in a mesh cell per unit volume per unit time for plasma species assuming the collision to be **an elastic ballistic collision**, m_n is the mass of a neutral atom, v_1 is the speed of the neutral atom before the collision, and v_2 is the speed of the neutral atom after the collision:

$$v_2 = \frac{2v_{d,i} + v_1\left(\frac{m_n}{m_i} - 1\right)}{\frac{m_n}{m_i} + 1}$$

Where m_i is the mass of plasma species i and $v_{d,i}$ is the drift velocity of plasma species I, $v_{d,i} = \mu_i |E|$.

System Coupling for EMA3D and Fluent – Step 3 – Fluent Simulation



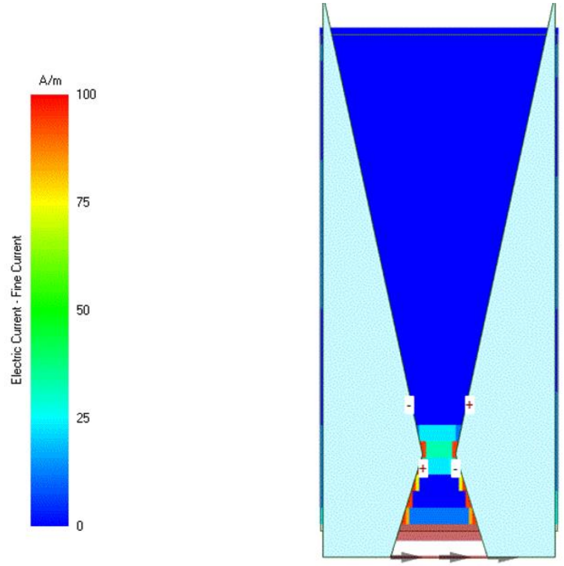
System Coupling for EMA3D and Fluent – What's next

For 2023R1:

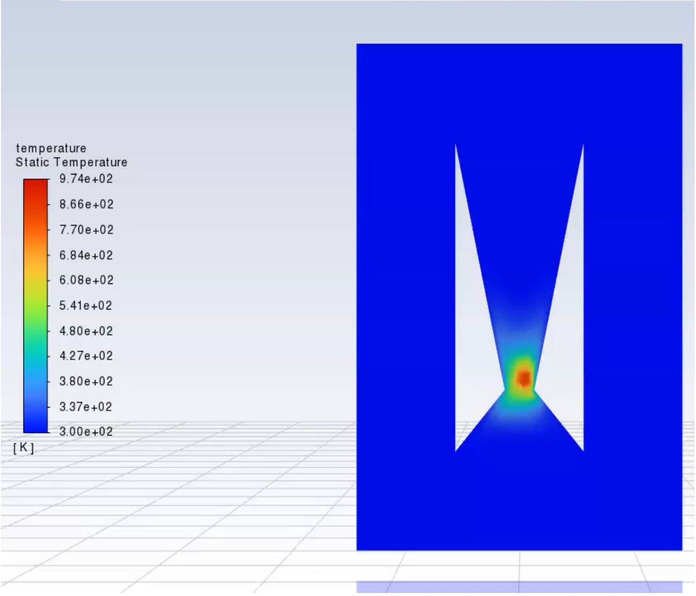
- No longer guess the arc temperature or location,
- Step 4 (calling of EMA3D Charge at each Fluent time step) is still under test,
- Optimization of time scales for data exchange is needed to ensure proper consideration of electromagnetic effects during propagation (problem dependent).

For 2023R2:

- Development of UI in Discovery for EMA3D Charge setup with System Coupling,
- Development of probes in EMA3D Charge to monitor temperature calculated by Fluent.



EMA3D Charge



Fluent

Highlight Feature:

Improved Surface Charging Methods for LEO, Auroral, and Interplanetary

Ansys

Analytical 3D Space Charge Simulations for Quicker Results

A lot of plasma environments do not need to be modeled with a full PIC solution.

Three analytic space charge calculations have been added to the PIC.

- Barometric
  - Used when surface potentials are comparable to or below the plasma temperature (or negative), especially when you have spacecraft wakes.

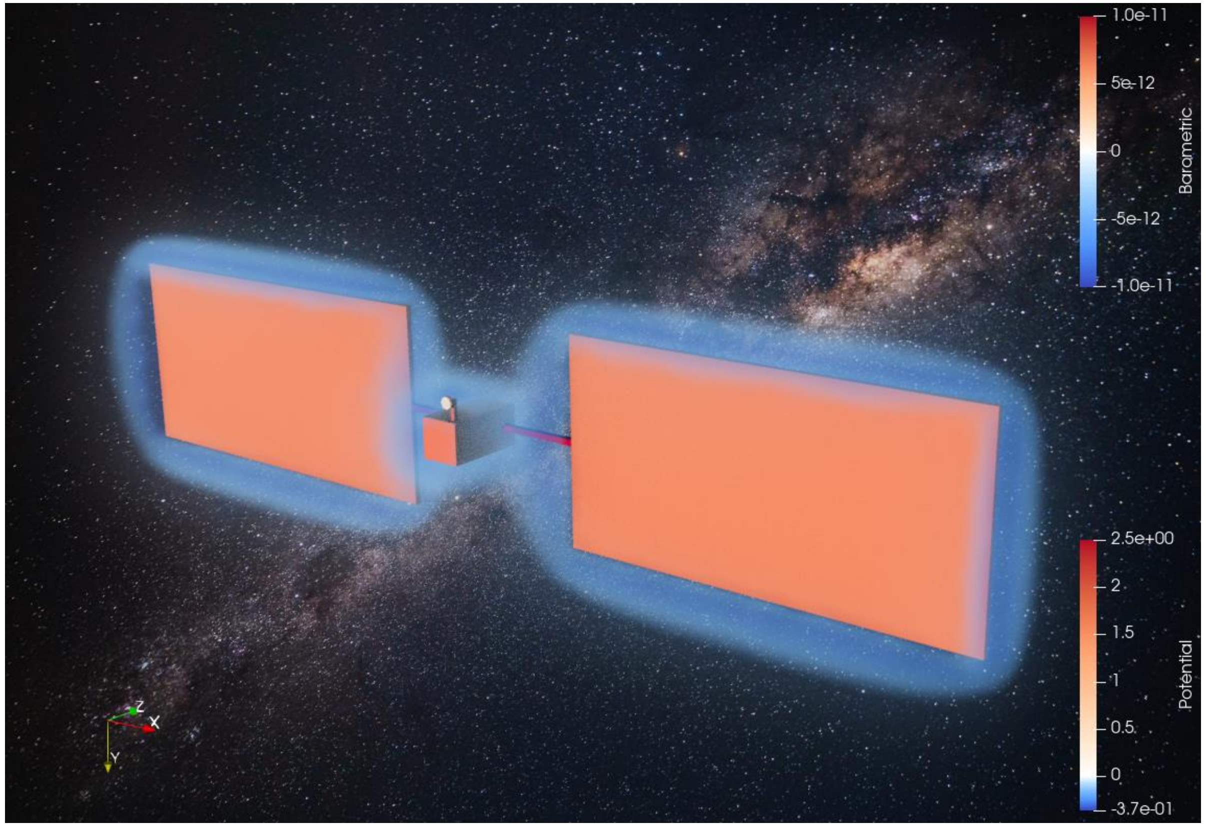
$$\frac{\rho_e}{\varepsilon_o} = -\frac{\rho_i^b}{\varepsilon_o}\begin{cases}\exp(\min(10, (\phi-\phi_b)/\theta_b)) & \text{for } \phi-\phi_b < 0 \\ 1+\min(10, (\phi-\phi_b)/\theta_b) & \text{for } \phi-\phi_b > 0\end{cases}$$

- Nonlinear
  - Used in high density plasmas when you have large applied potentials, such as is common with high voltage solar panels.

$$\rho/\varepsilon_0 = -\left(\phi/\lambda_{nl}^2\right)\frac{\max\left(1, C(\phi, E)\right)}{1+\sqrt{4\pi}\left|\phi/\theta_{nl}\right|^{3/2}}$$

- Hybrid
  - Uses PIC particle tracking for ions and barometric space charge calculations for electrons.
  - Used when ion trajectories are important, but electrons are appropriately simulated analytically. Useful for long time stepping or when the satellite speed is much slower than the electrons but on the same order as the ions.

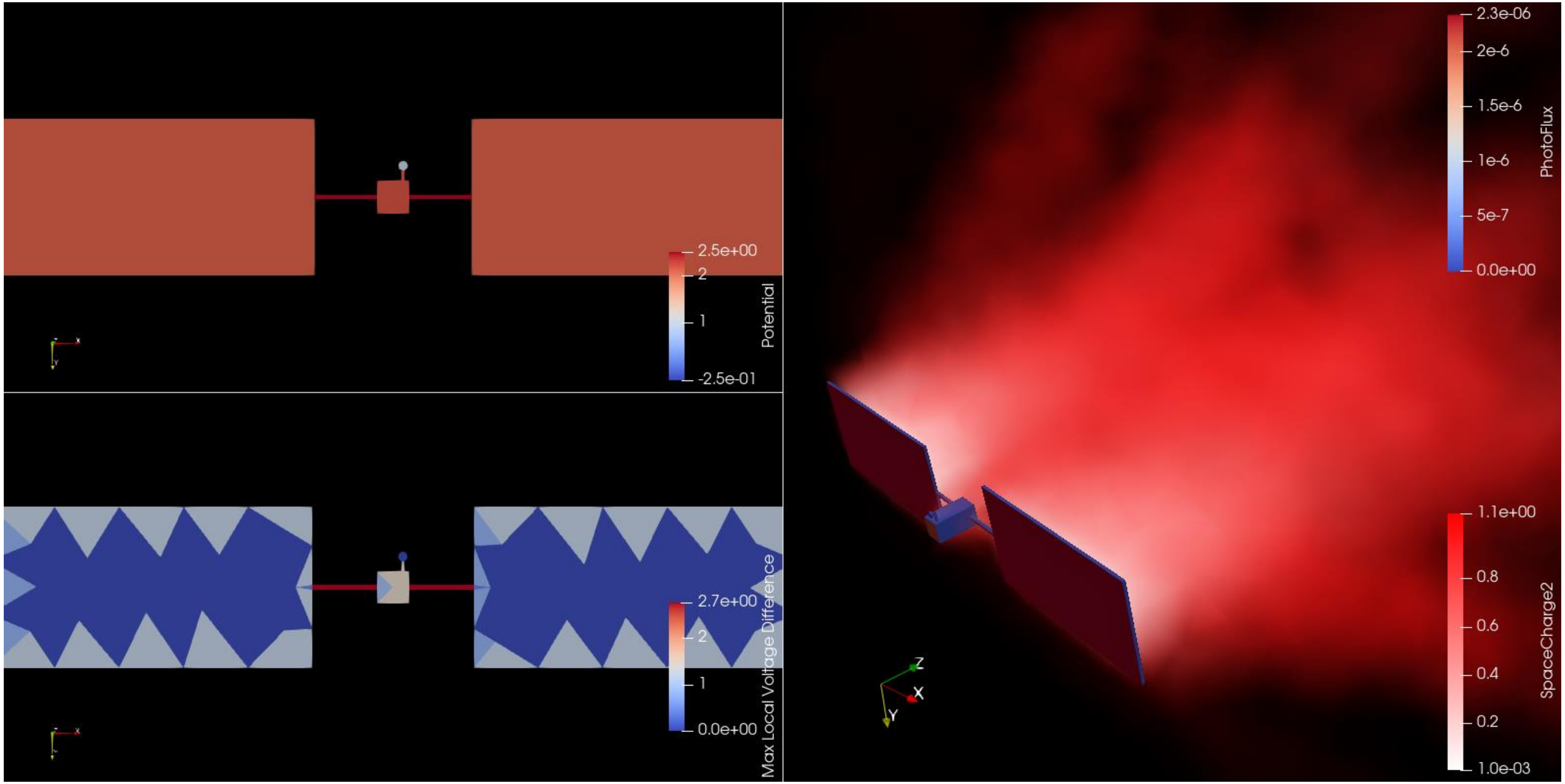
$$\frac{\rho_e}{\varepsilon_o} = -\frac{\rho_i^{hp}}{\varepsilon_o}\begin{cases}\exp(\min(10, (\phi-\phi_b)/\theta_{hp})) & \text{for } \phi \le 0 \\ \exp(\min(10, -\phi_b/\theta_{hp}^0))(1+\phi/\theta_{hp}) & \text{for } 0 < \phi\end{cases}$$



Plasma Sheath

Analytical 3D Space Charge Simulations for Quicker Results

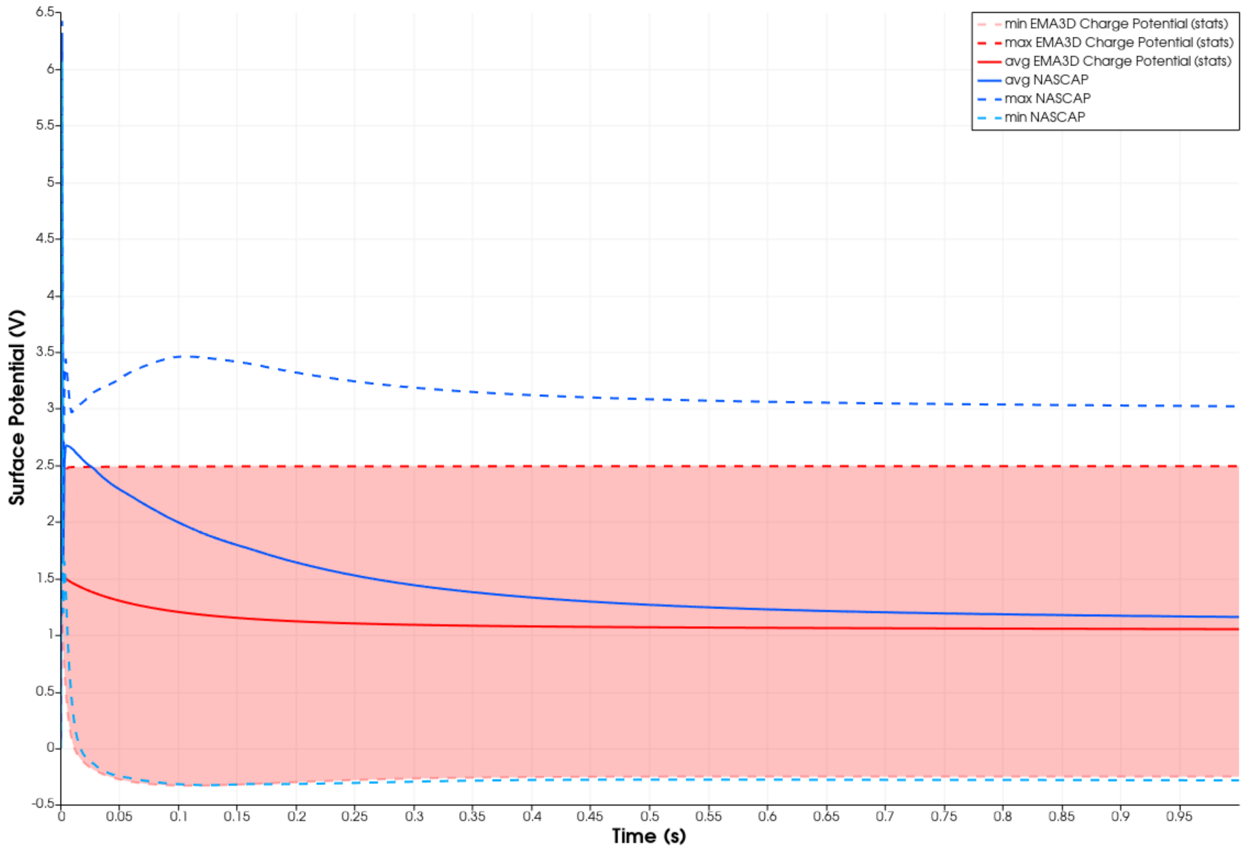
Those low voltages may not be that low when changing material properties!

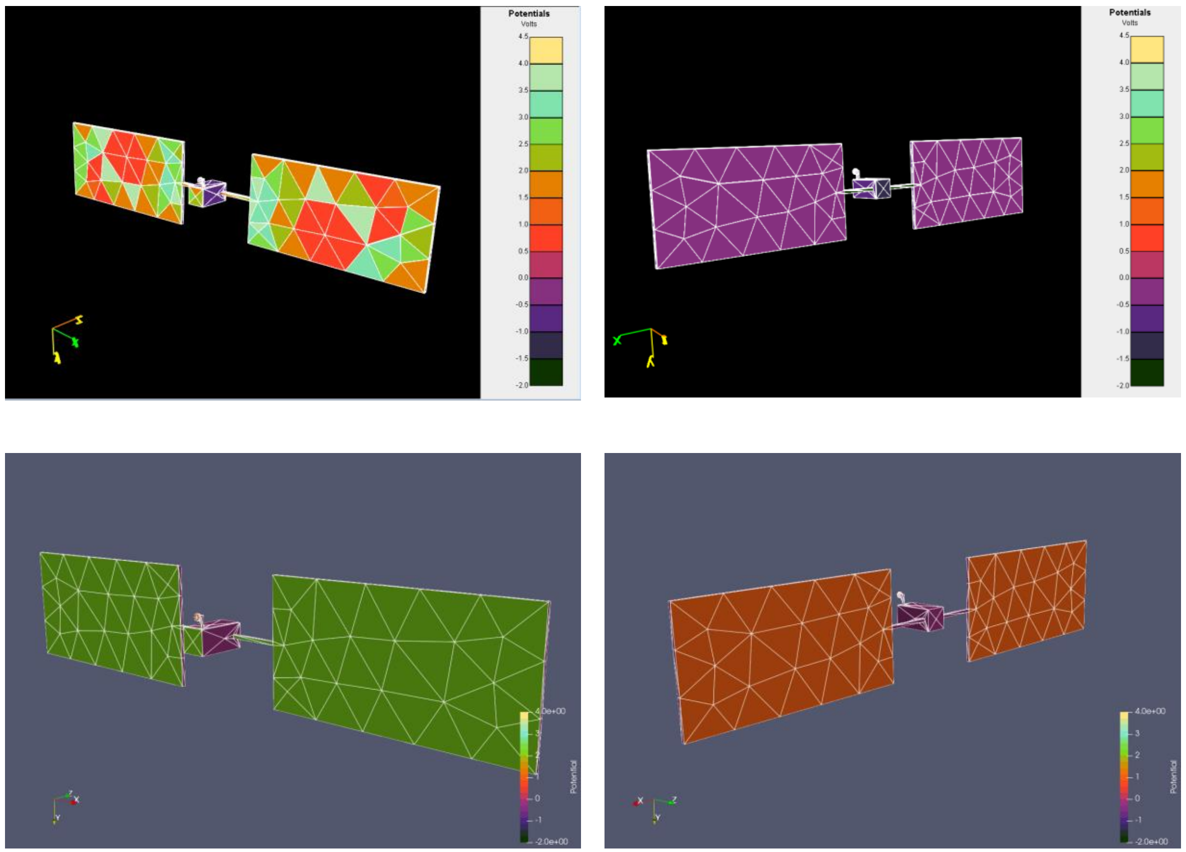


Plasma Wake

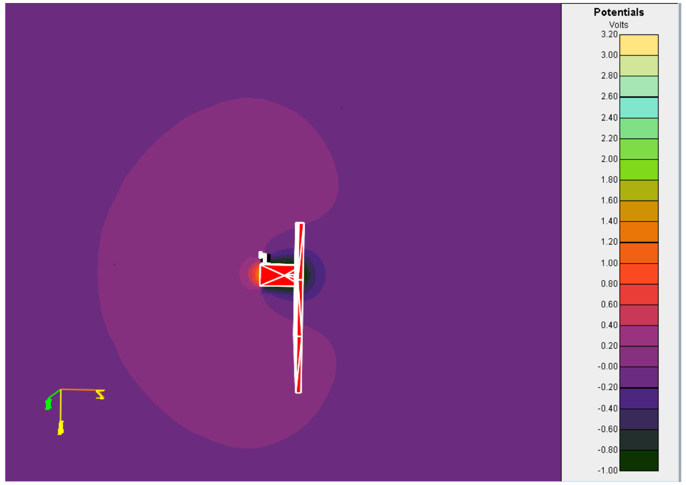
Barometric Results Compare well with Other Tools

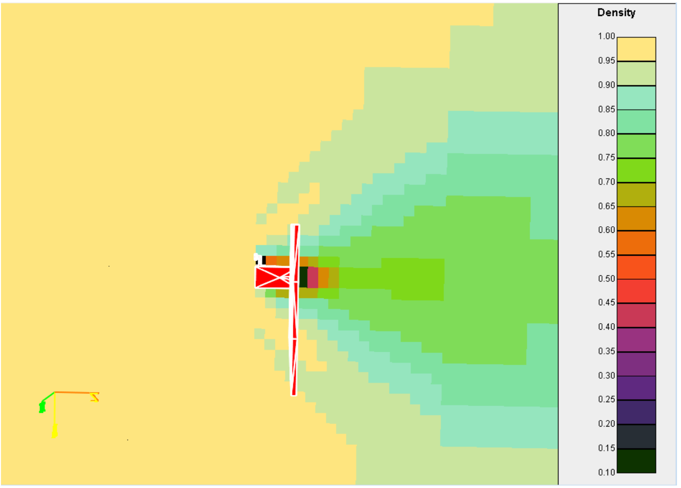
Difference in surface potential is key for engineers to assess the risk of ESD!

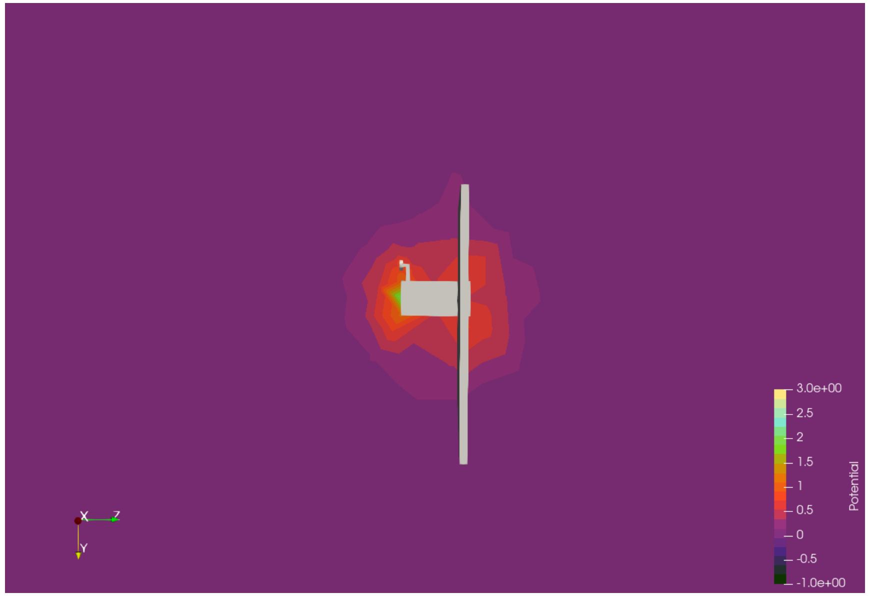


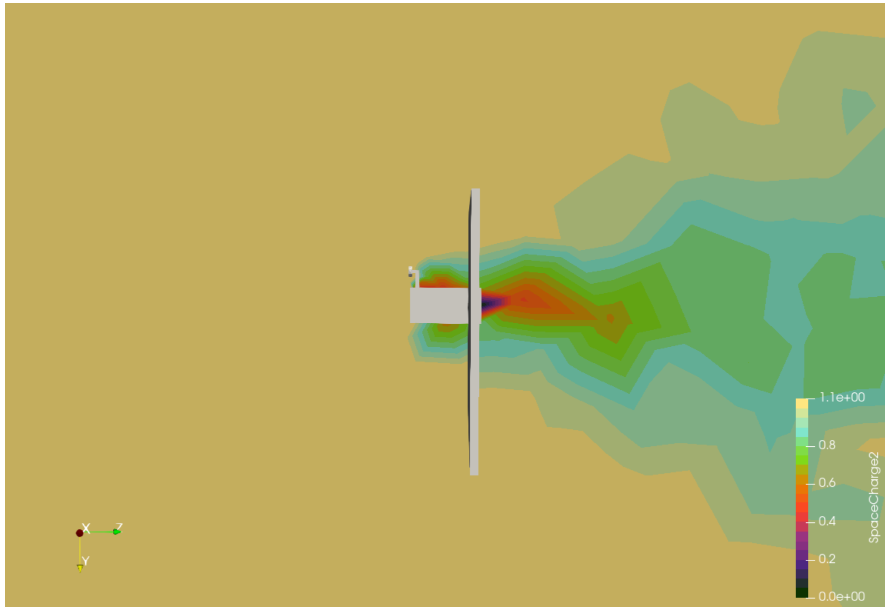


Barometric Results Compared with NASCAP





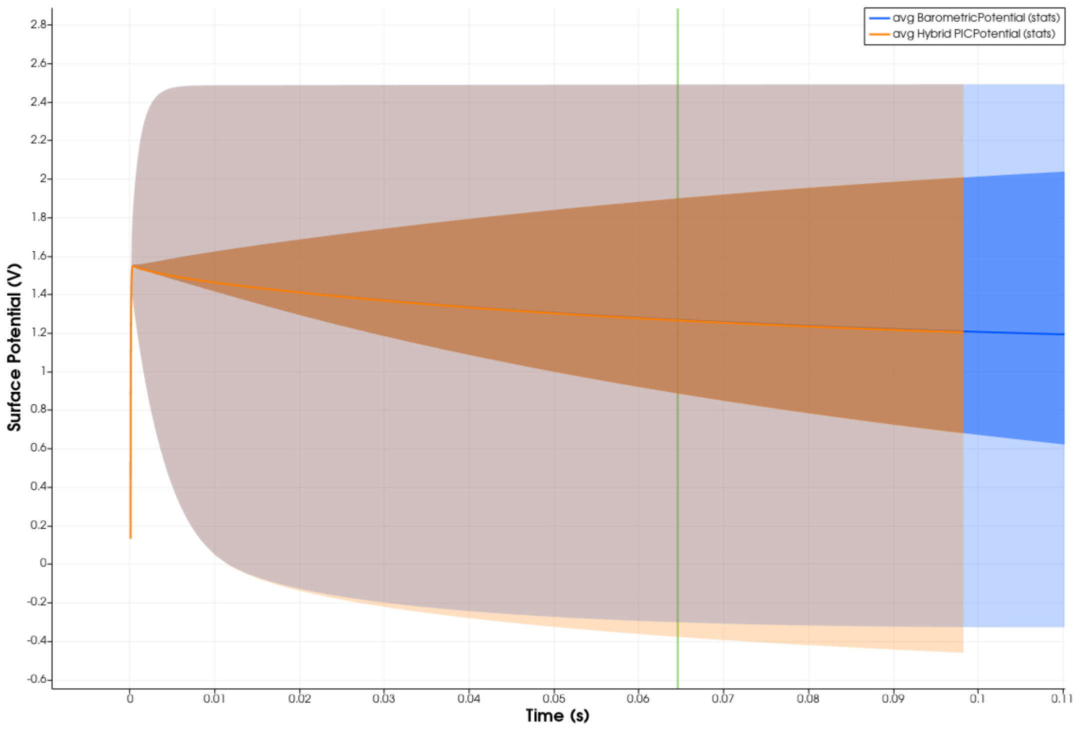


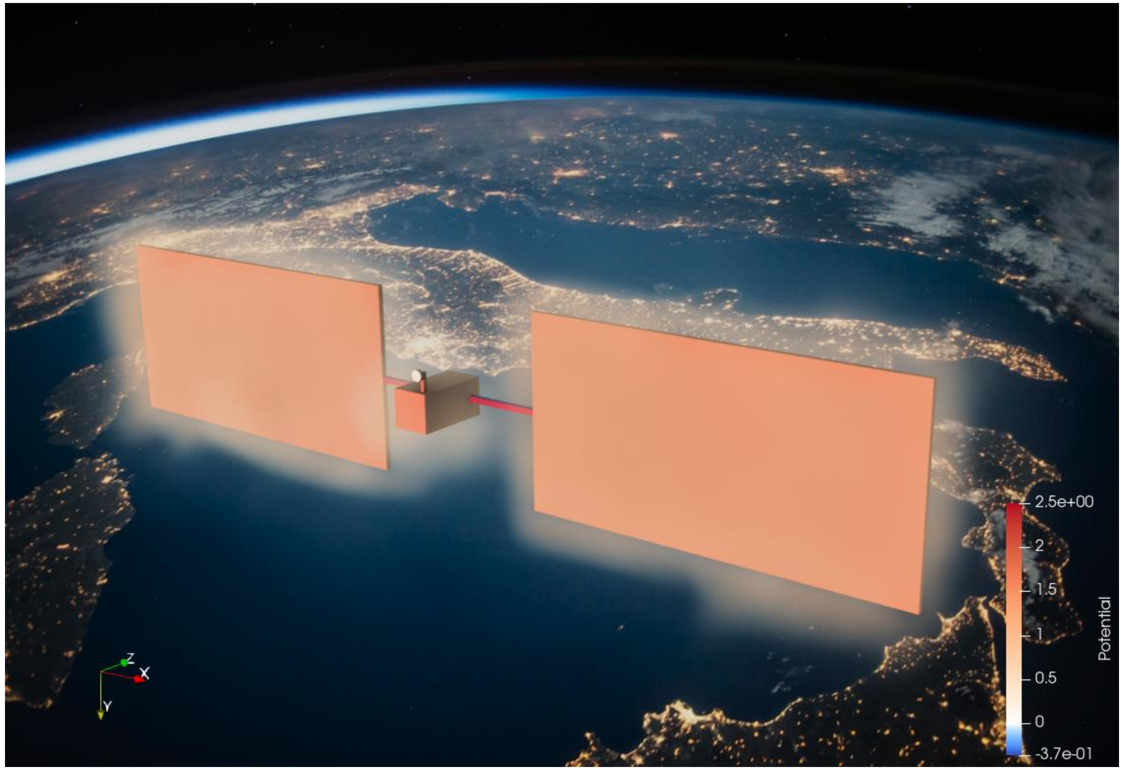


Ansys

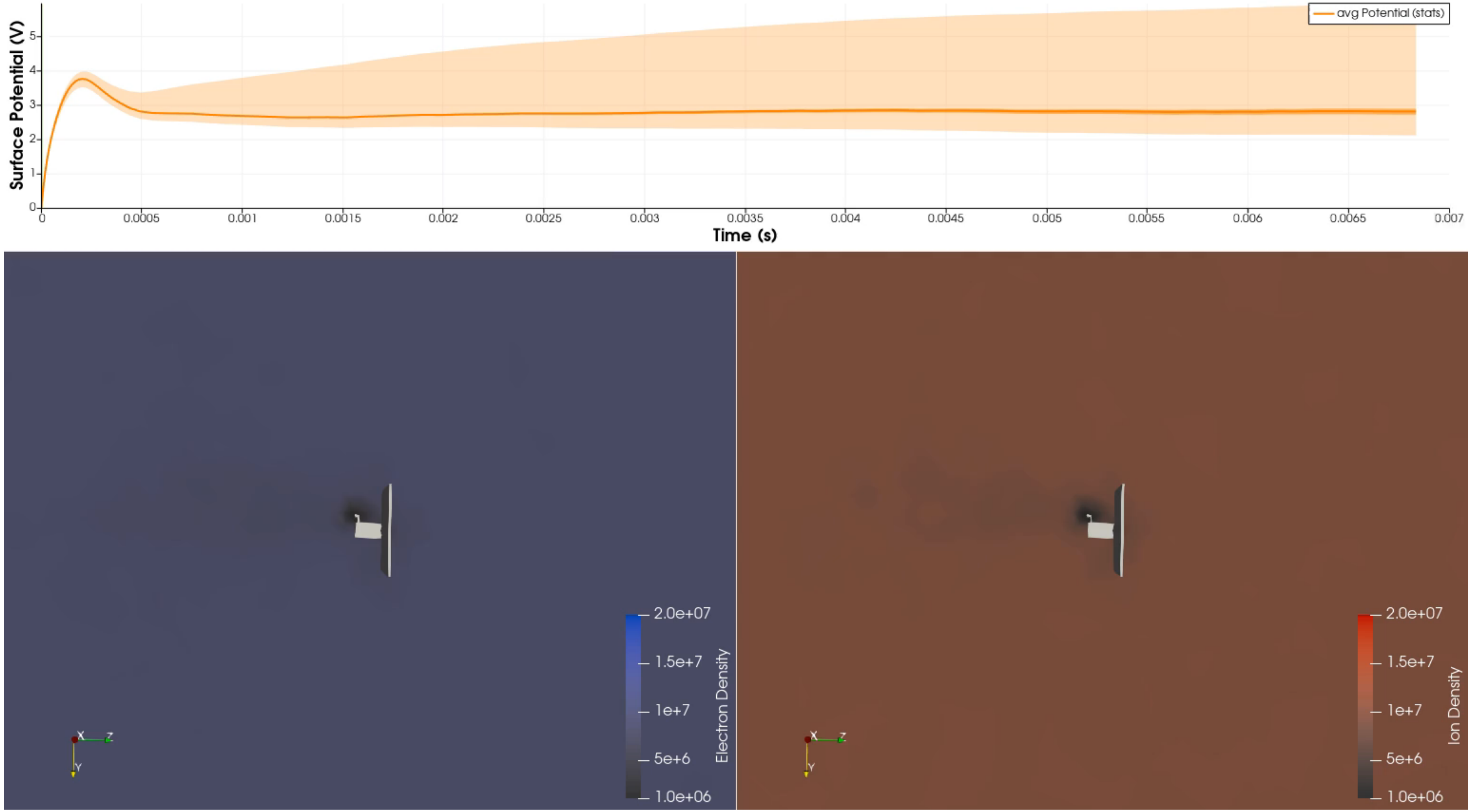
Hybrid PIC Results Compare Well with Barometric Results!

Get results in a fraction of the time with the Barometric model (less than an hour, instead of a week!)





Full PIC Results – Highly Detailed Plasma Dynamic Simulation



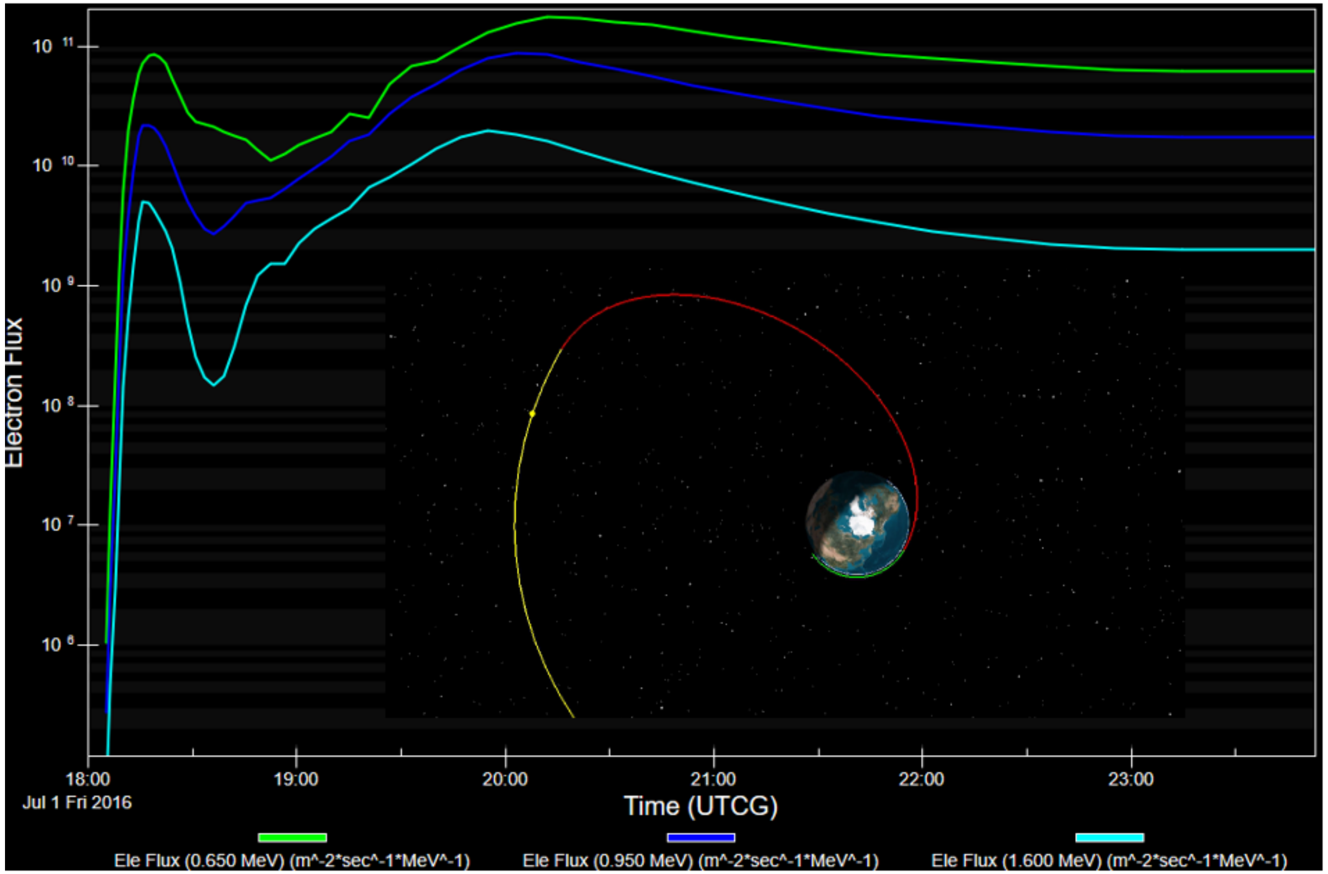
Highlight Feature: Integration with Ansys STK

Ansys

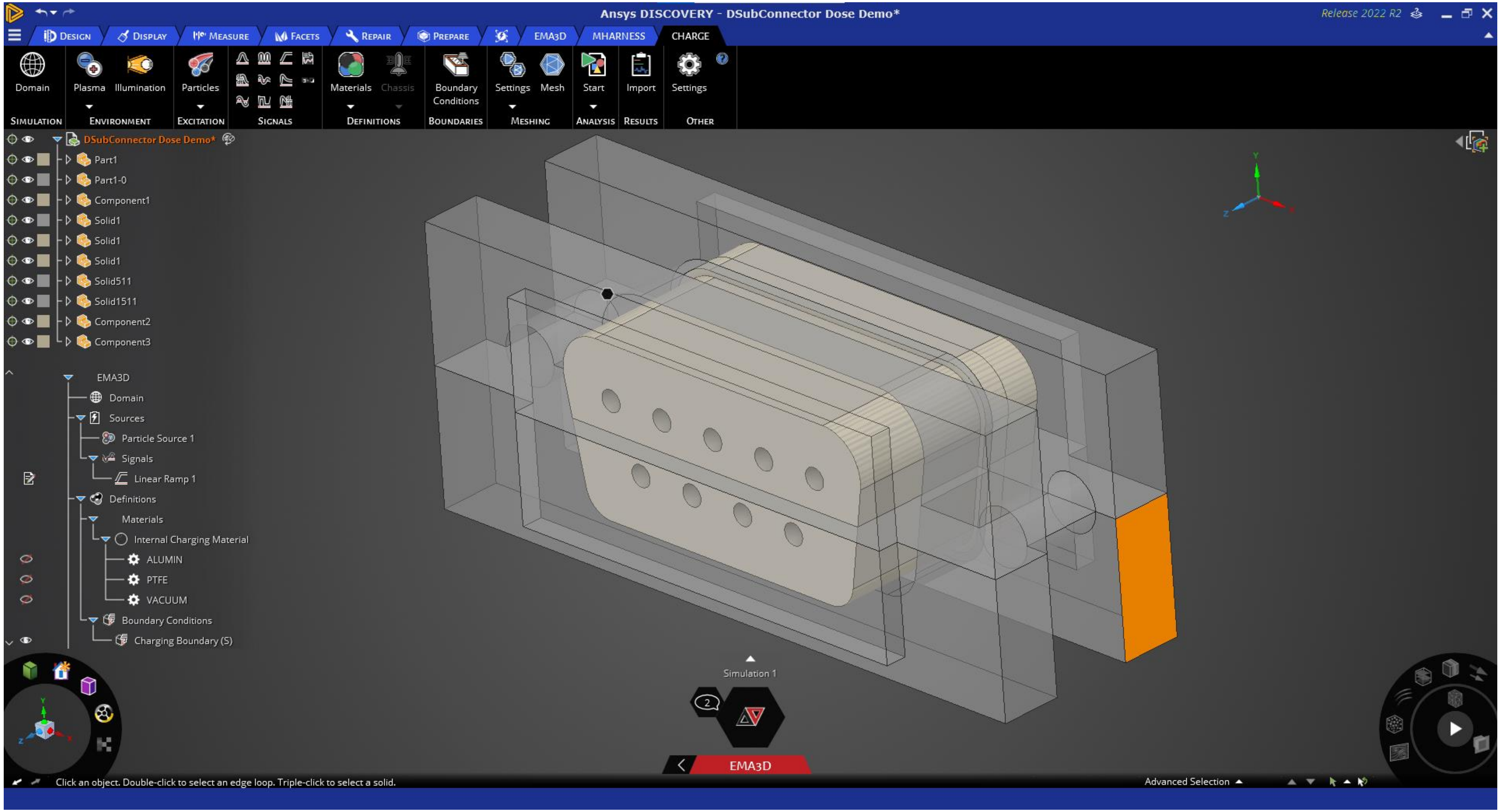
Integration with AGI-STK

Using worse-case scenarios is not always necessary – to make it easy to refine the analysis on a per-mission basis, EMA3D Charge is seamlessly integrated with Ansys STK.

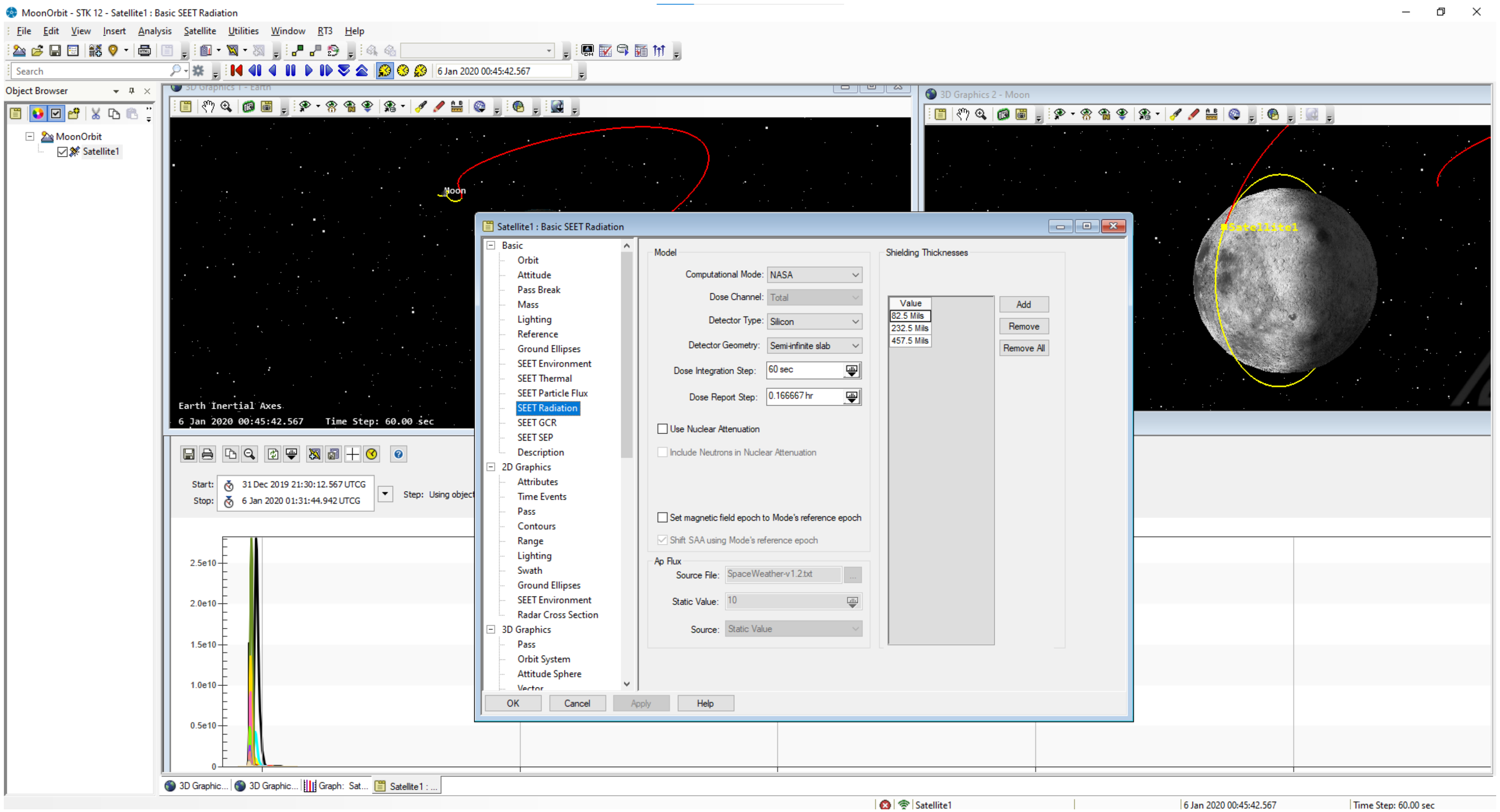
- User starts with ephemeris file for mission
- **STK-SEET** exports the high-energy particle spectrum over time for the mission
- Discussing plans for low energy spectrum as well.
- EMA3D Charge takes the plasma parameters versus time as an input and computes the coupled surface and internal charging, self-consistently
- Users can evaluate the performance of their equipment and electronics in 3D



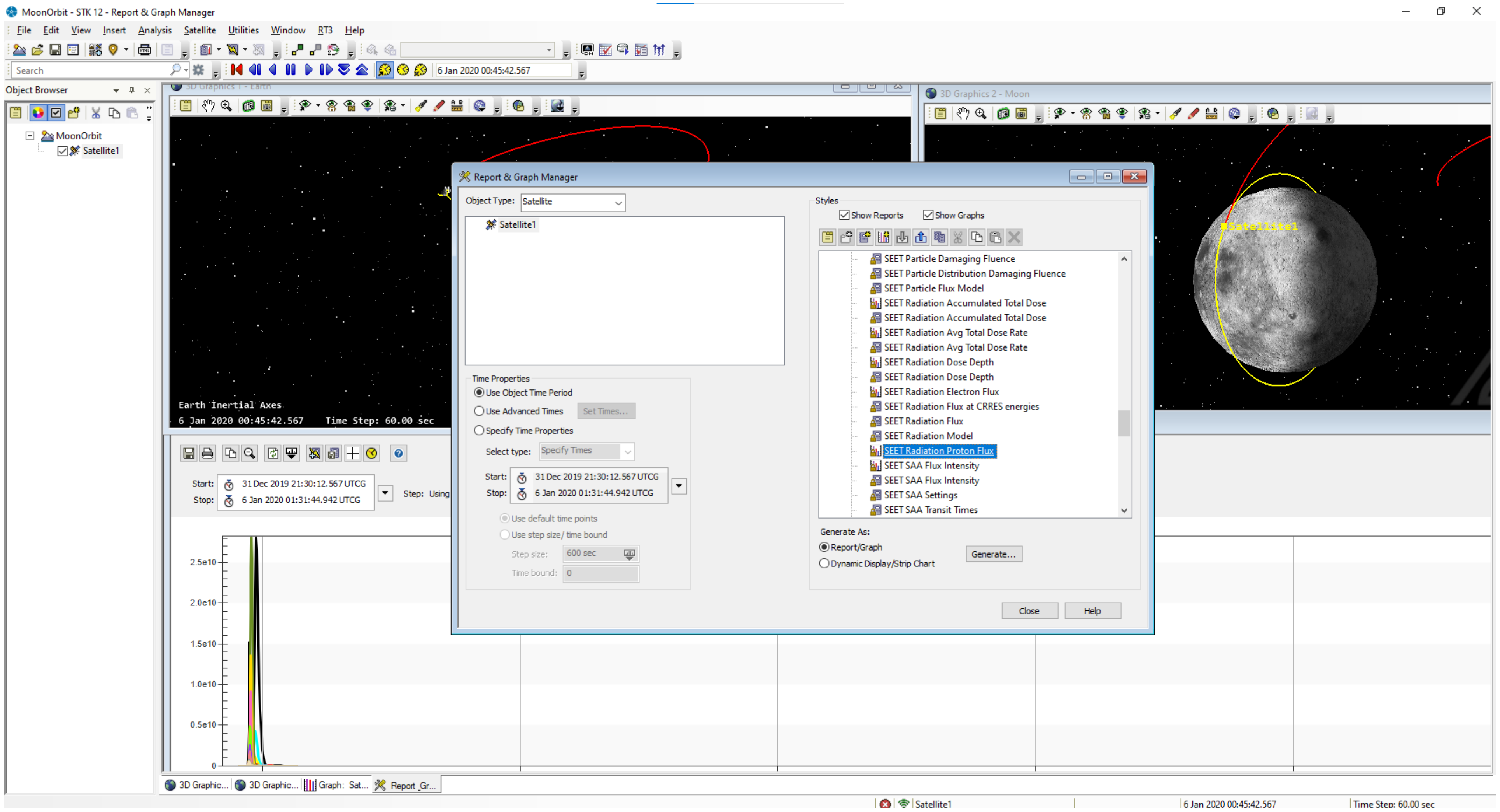
Internal Charging of D-Sub Connector



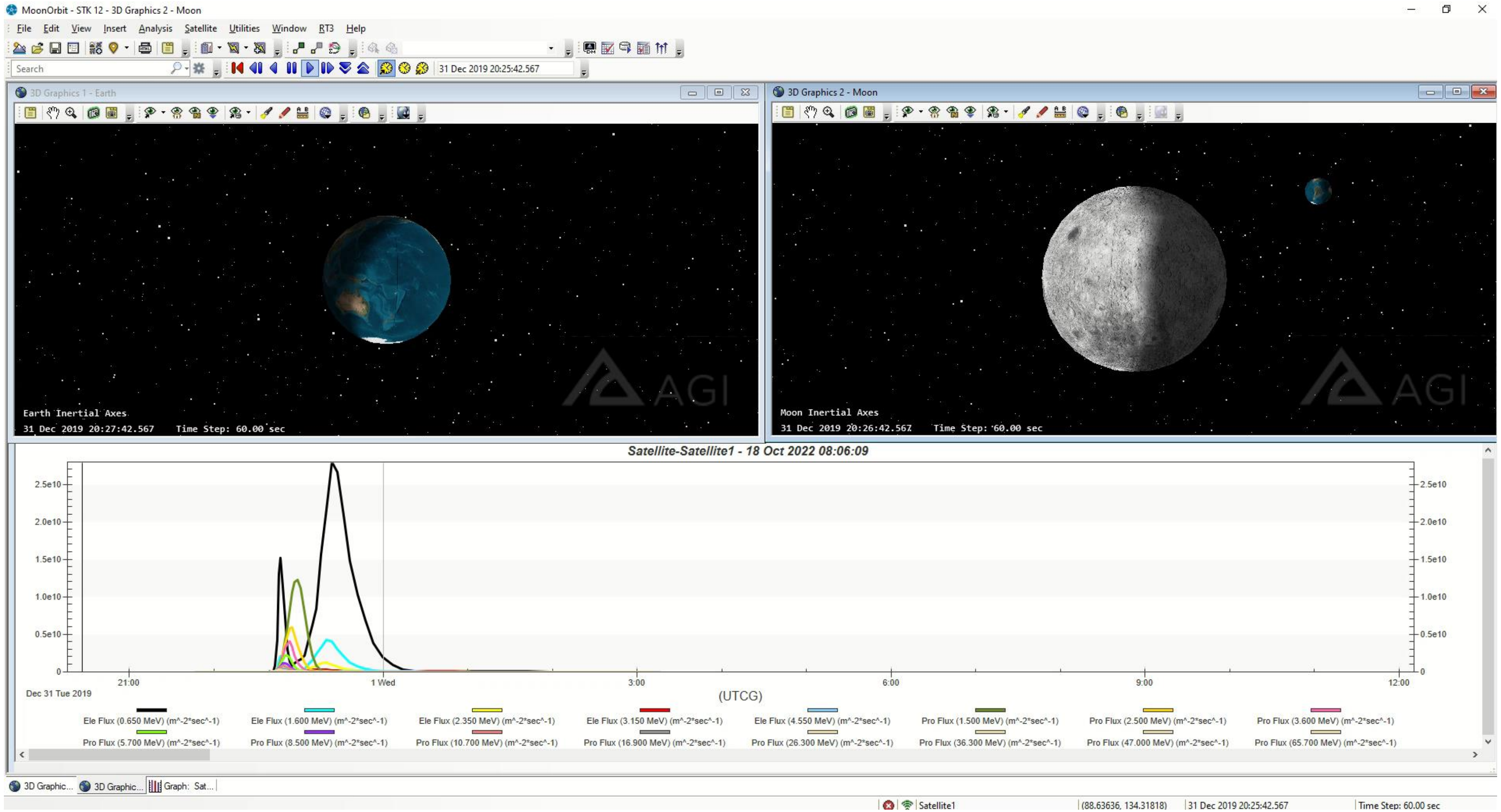
Integration with AGI-STK – How to Get Fluences from SEET



Integration with AGI-STK – Getting Radiation Reports



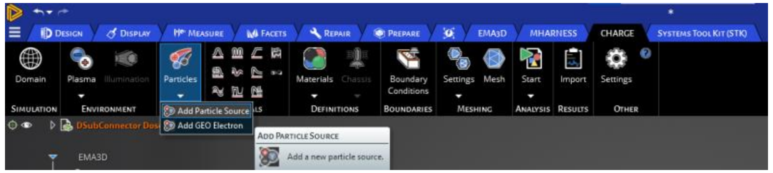
Integration with AGI-STK – How to Get Fluences

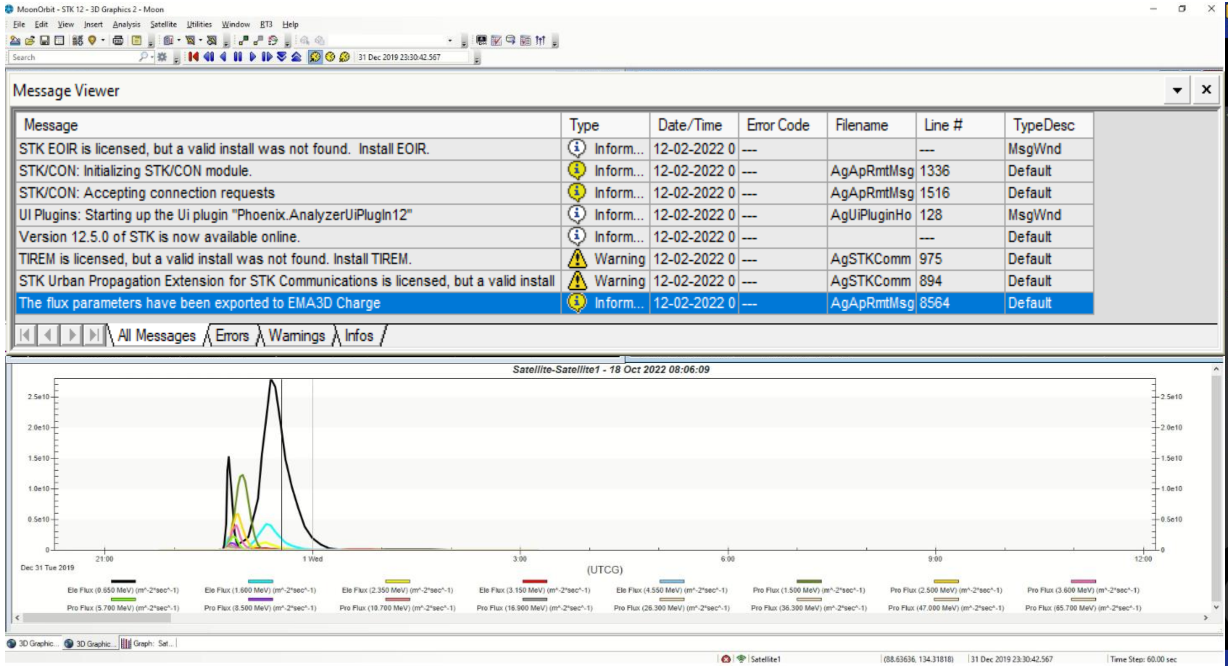


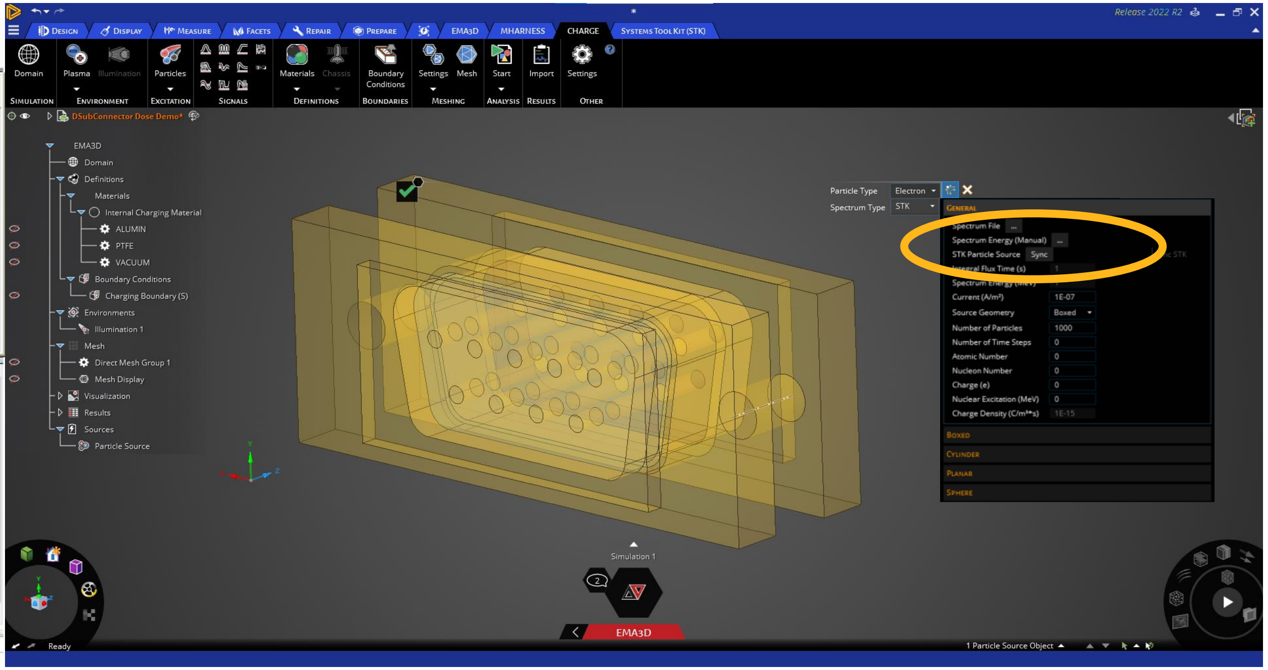
Integration with AGI-STK – Sync Between Two UIs

1) Set time domain of charging simulation to used parse STK spectrum automatically
2) Automatic sync between the two tools
3) Data saved in EMA3D Charge for model engineering

Create a New Particle Source

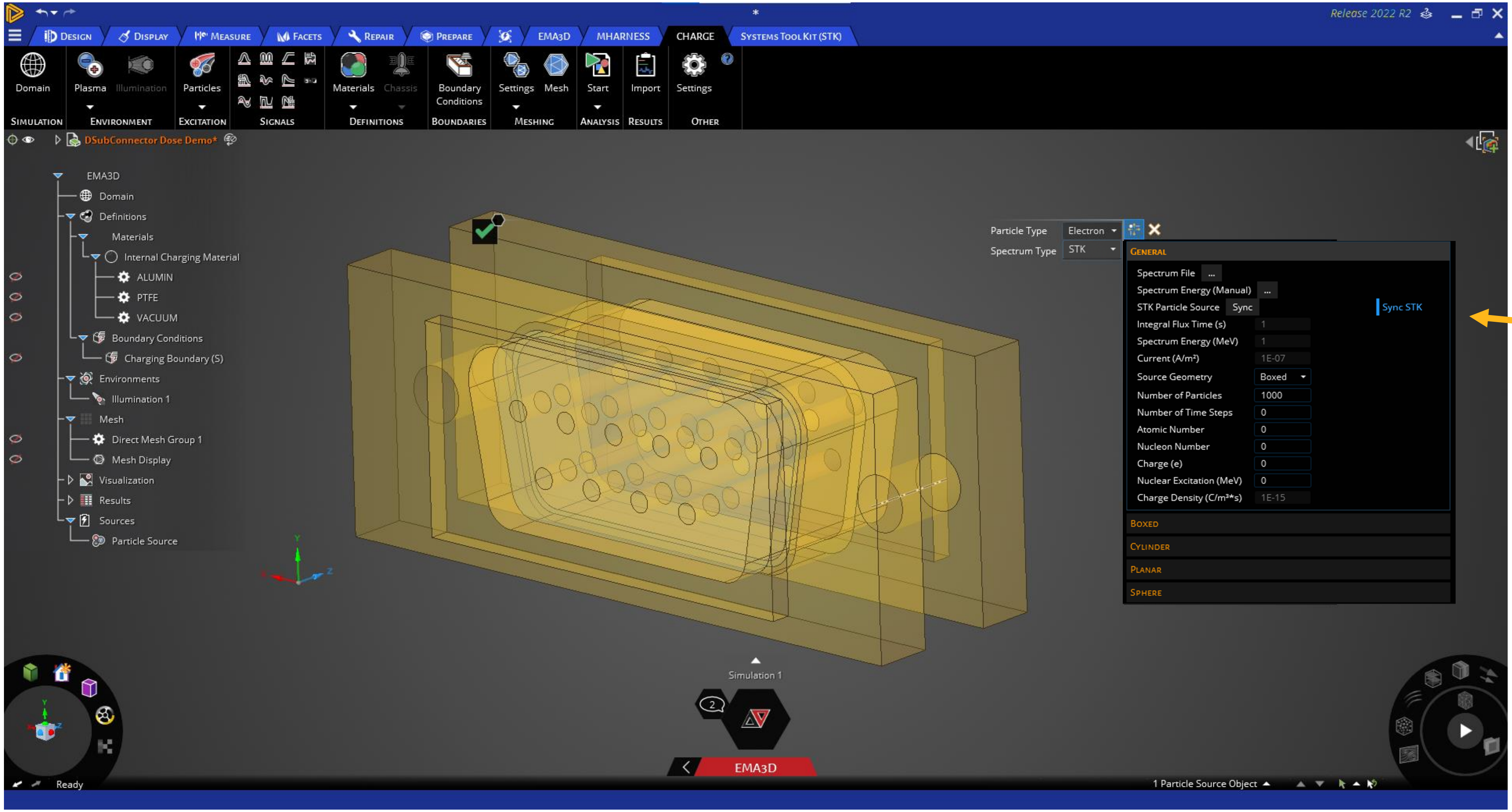






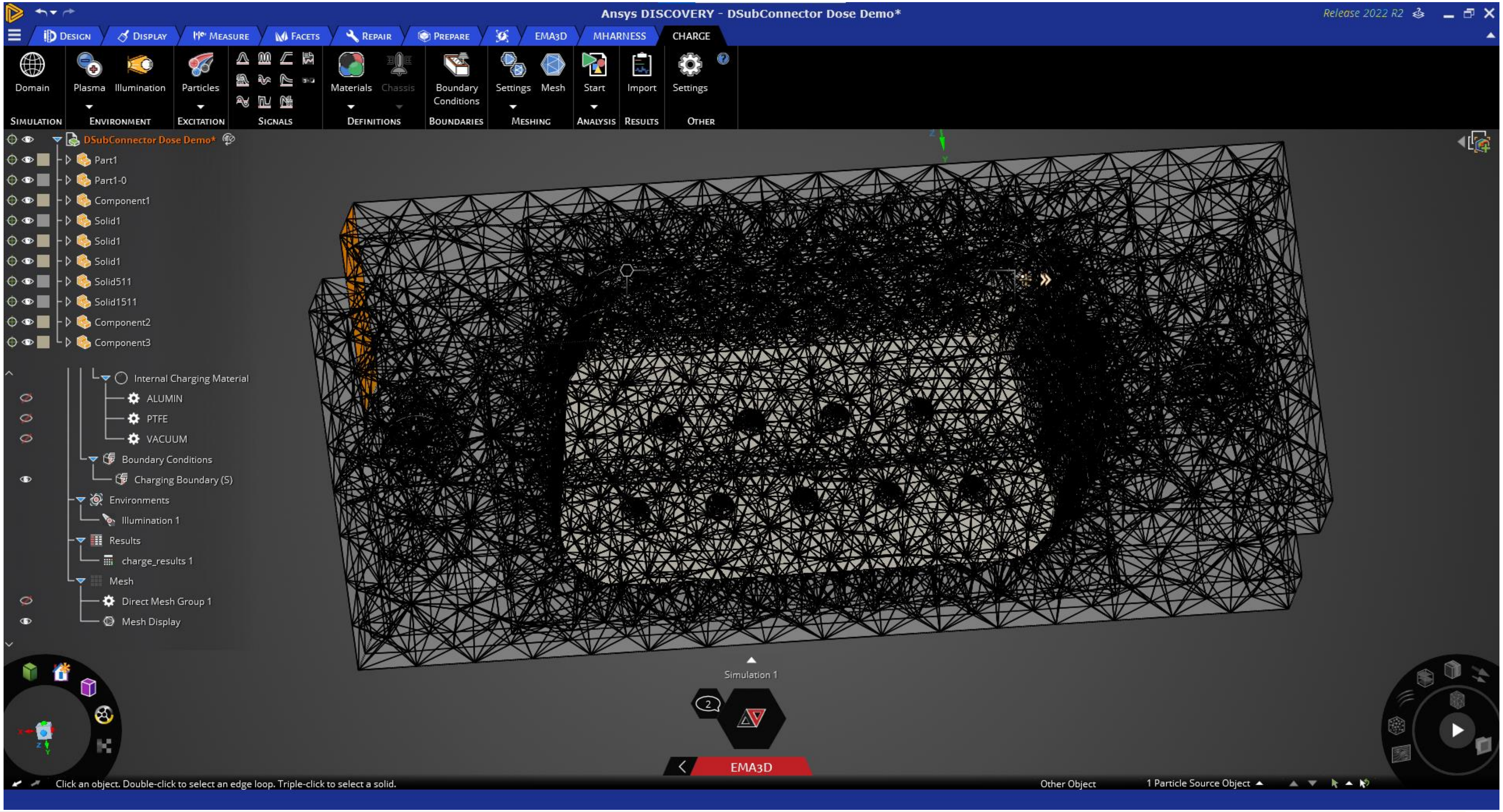
Integration with AGI-STK – STK Data Saved in Charge Model

Use both protons and electrons and select source geometry and time domain for particle transport

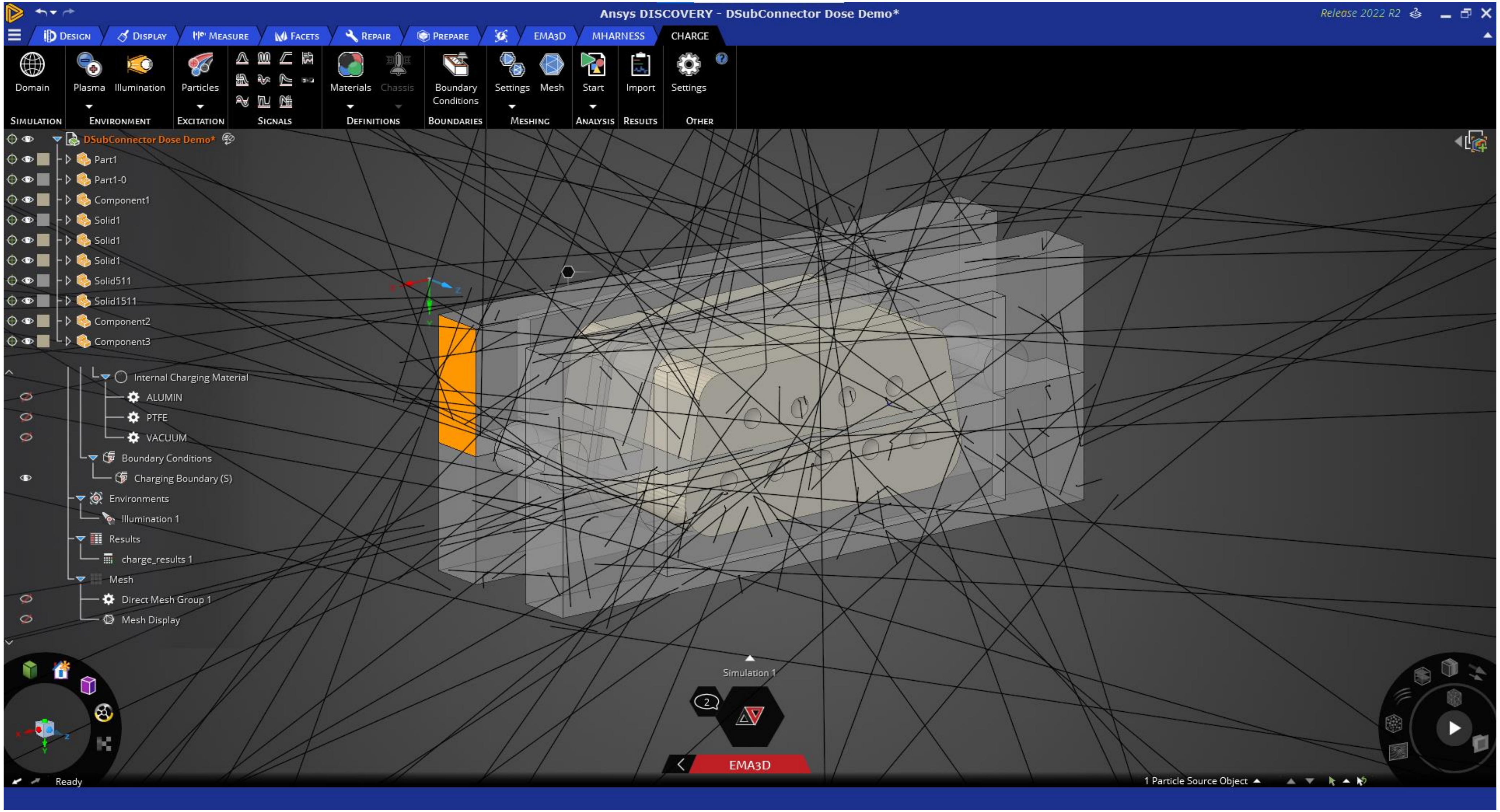


STK is Synced!

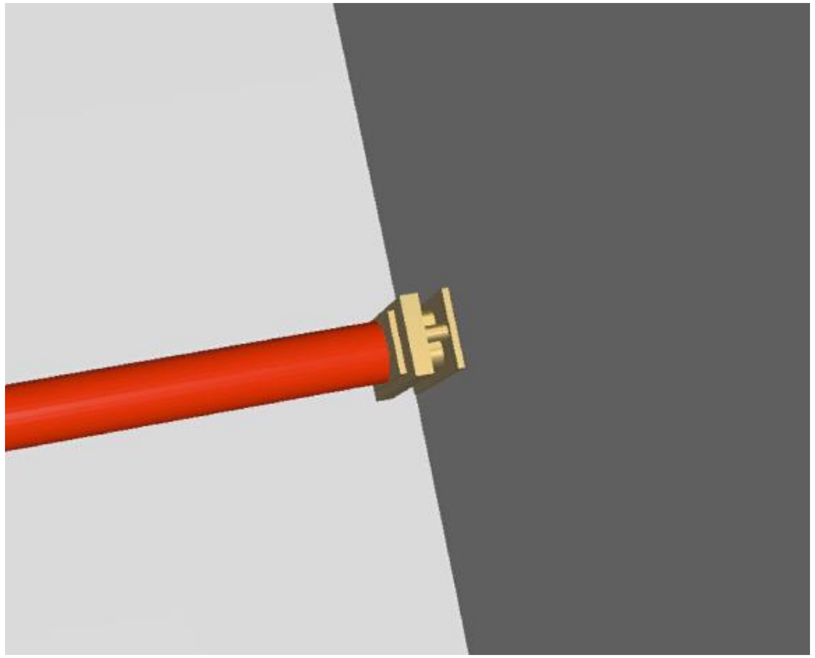
Internal Charging in GEO – Mesh Group on Dielectric

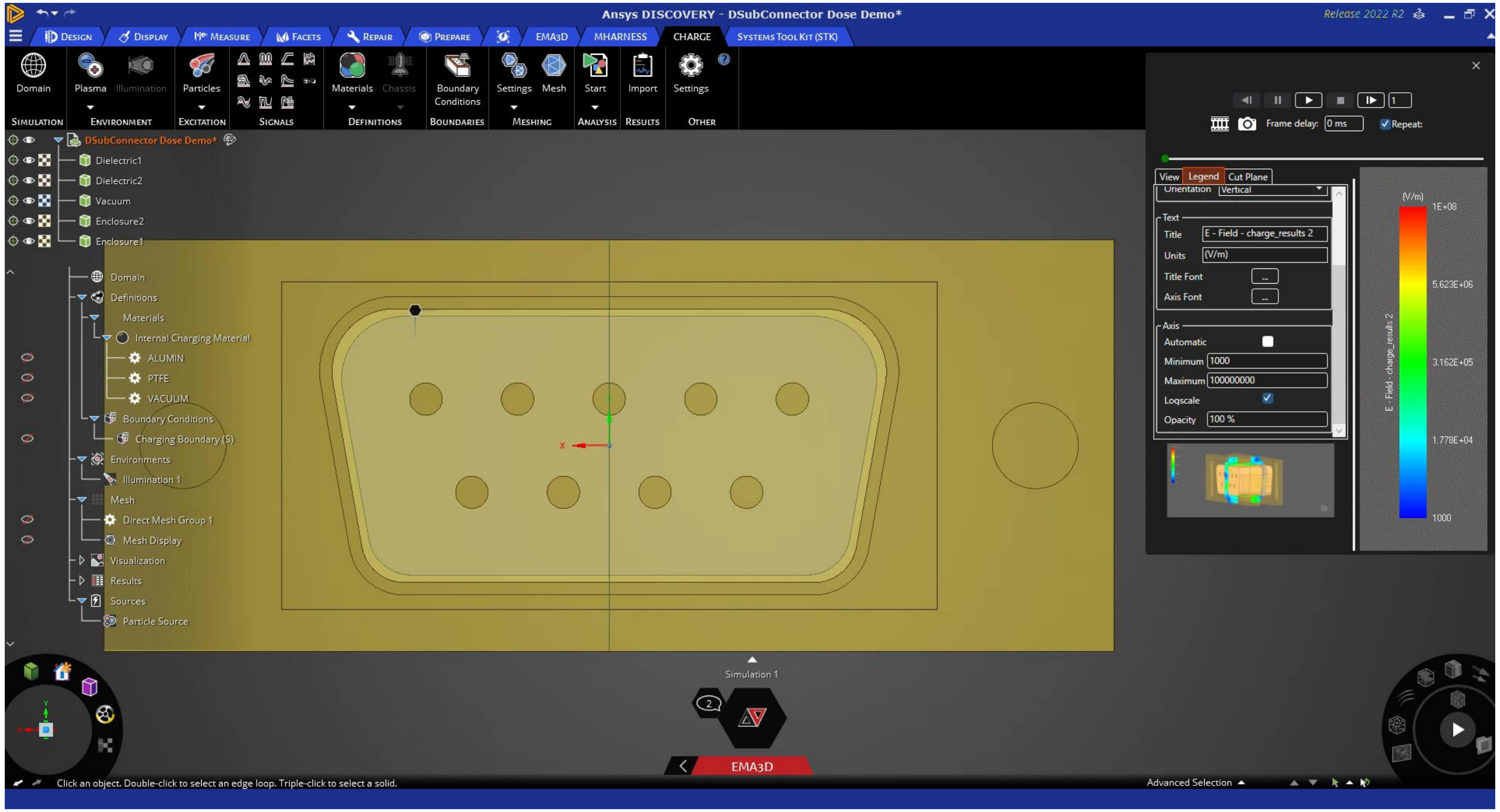


Internal Charging in GEO – Electron Tracks

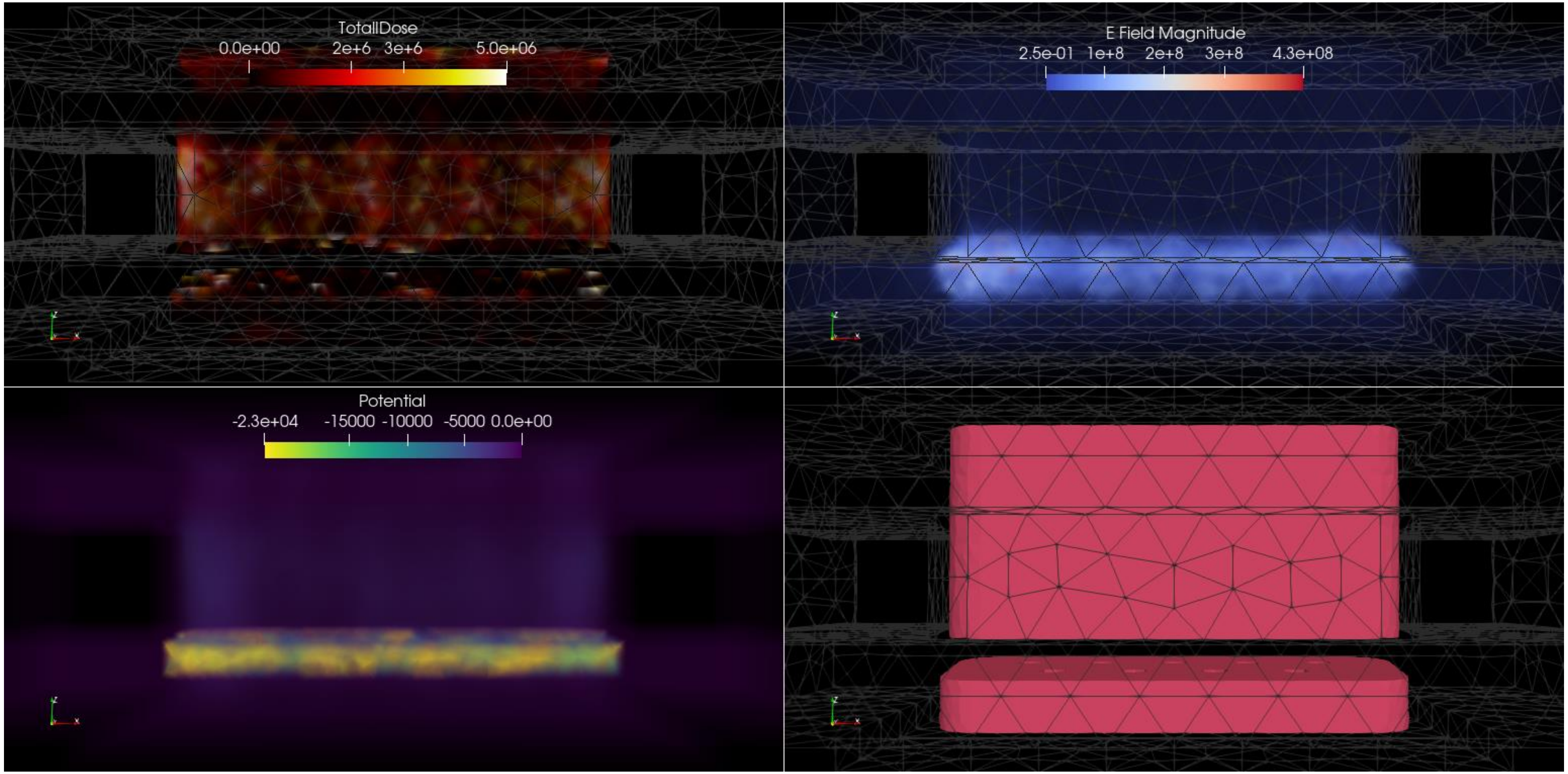


Internal Charging Results of Connector





Internal Charging in GEO – Results in Post Processing Tool



FluxDens

IDose

LET

NonIDose

TotalIDose

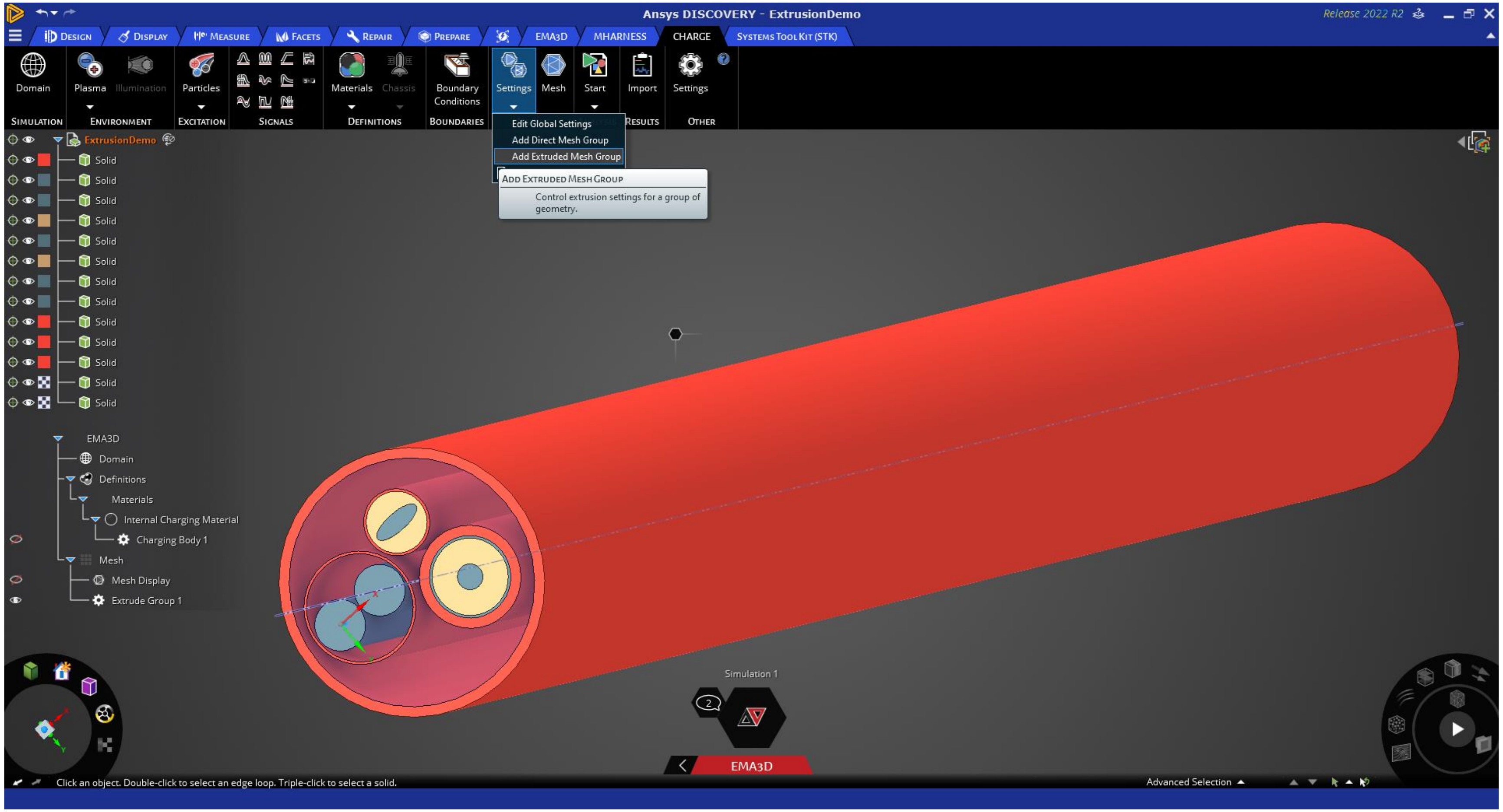
TotalLET

TotalNonIDose

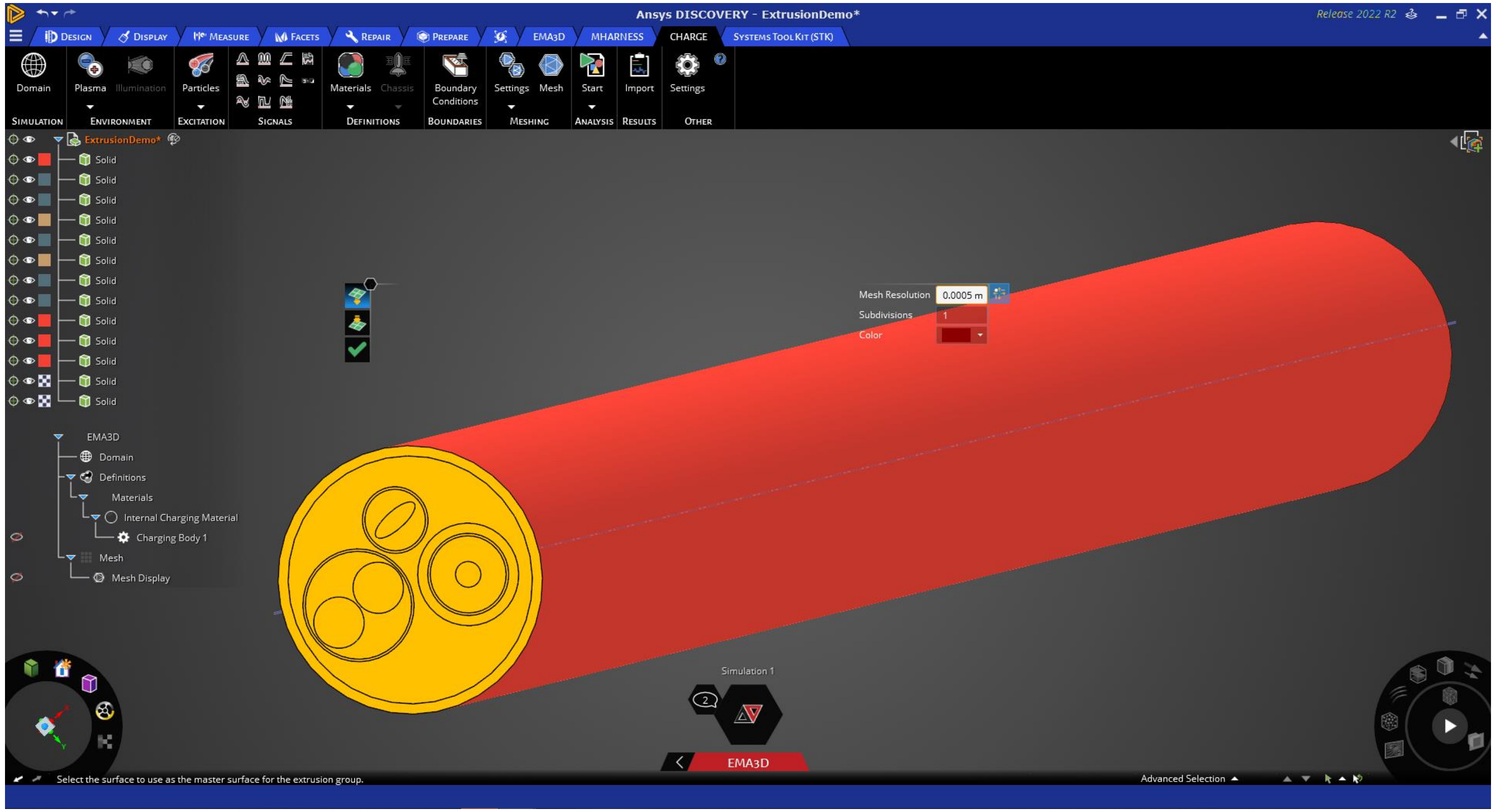
Additional Features

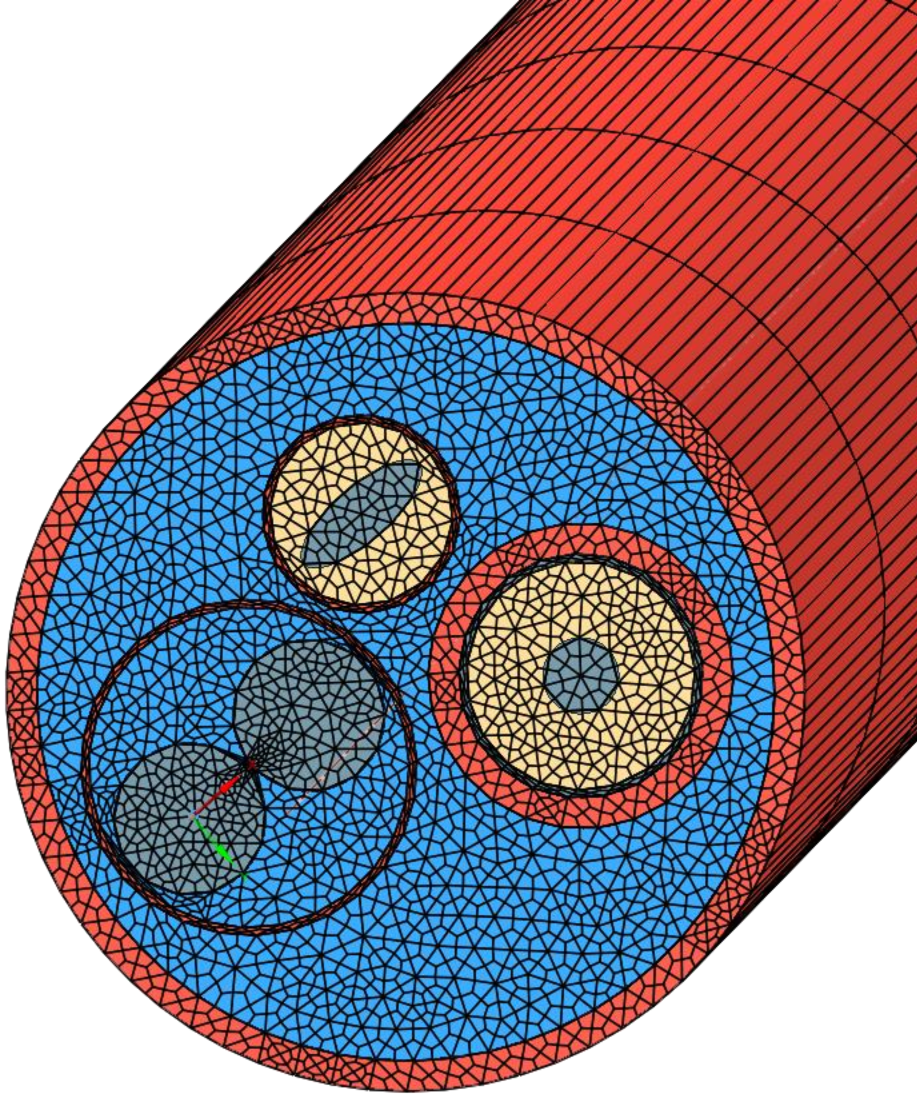
Extrusion Group Update

- Optimized workflow by selecting front and end of cable
- Automatic calculation of extrusion vector
- No more ridiculous aspect ratios
- Much faster
- Any lengths

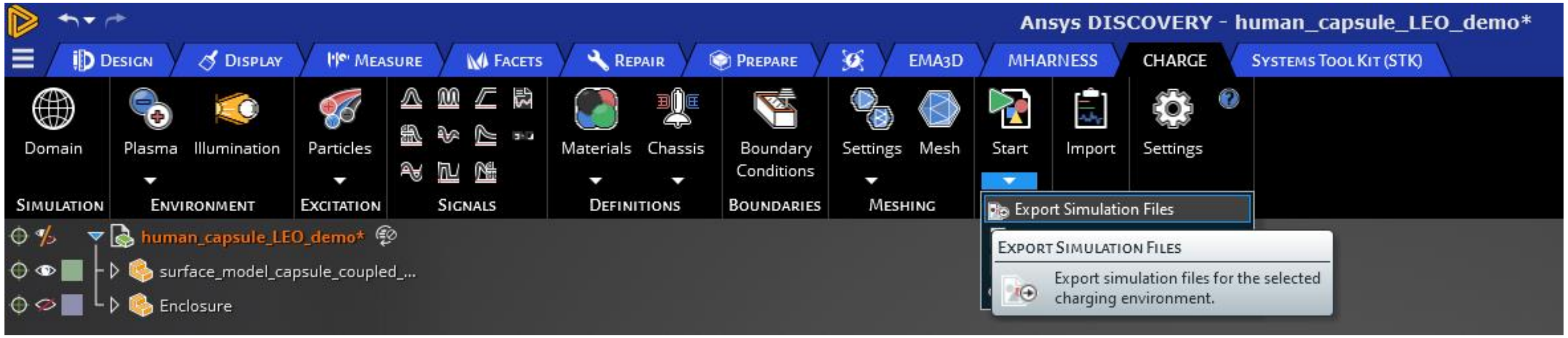


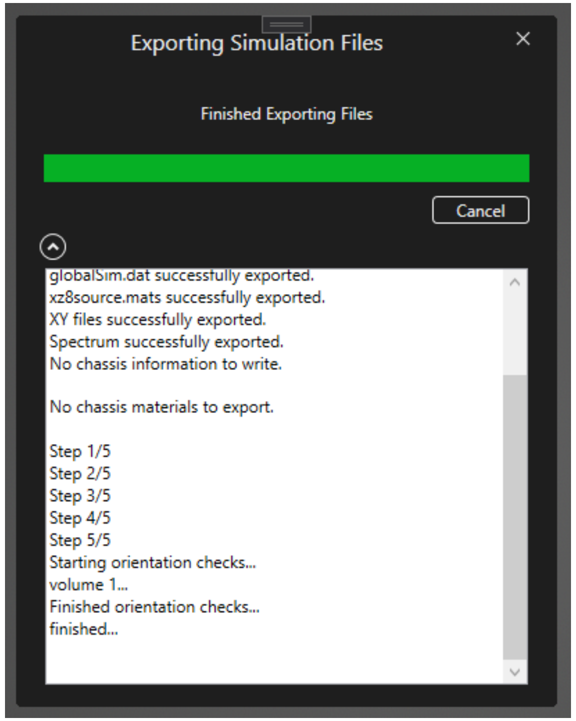
Extrusion Group Update

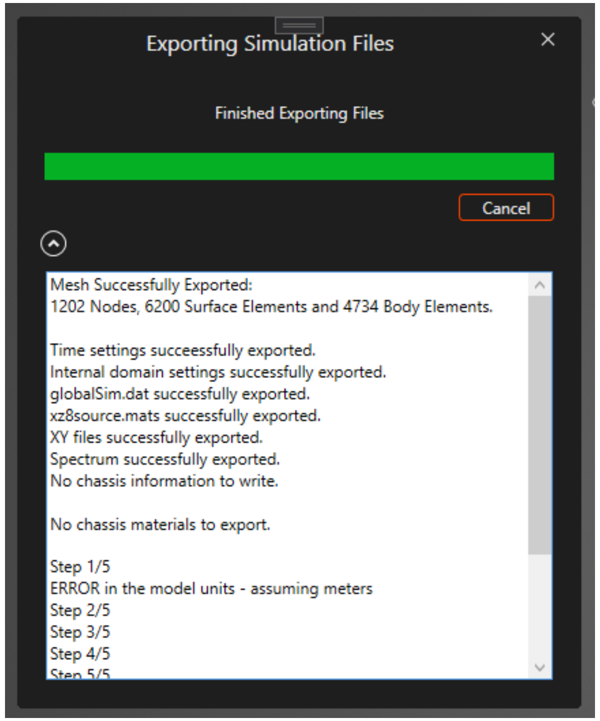




Export and Pre-processing Progress and Warnings

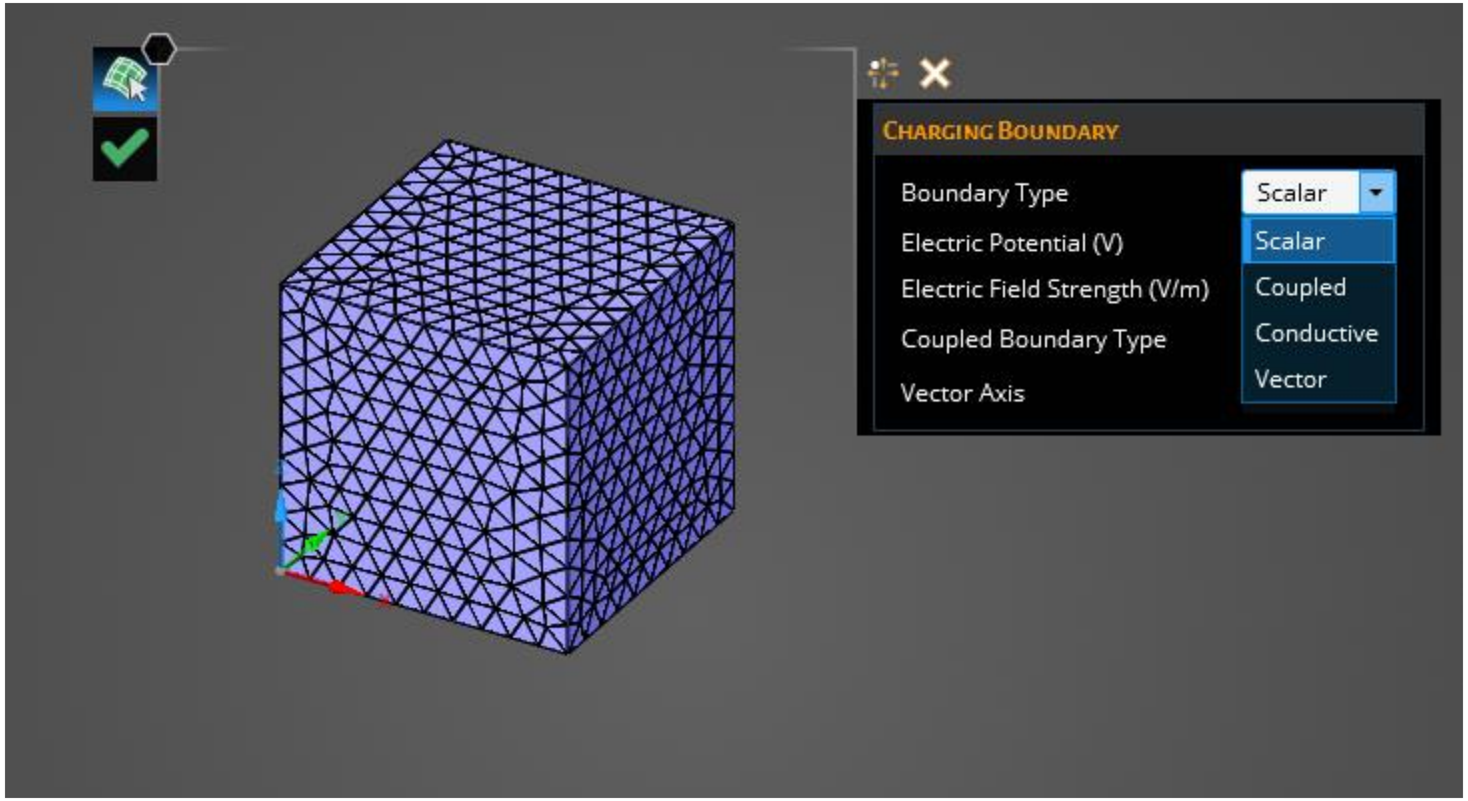




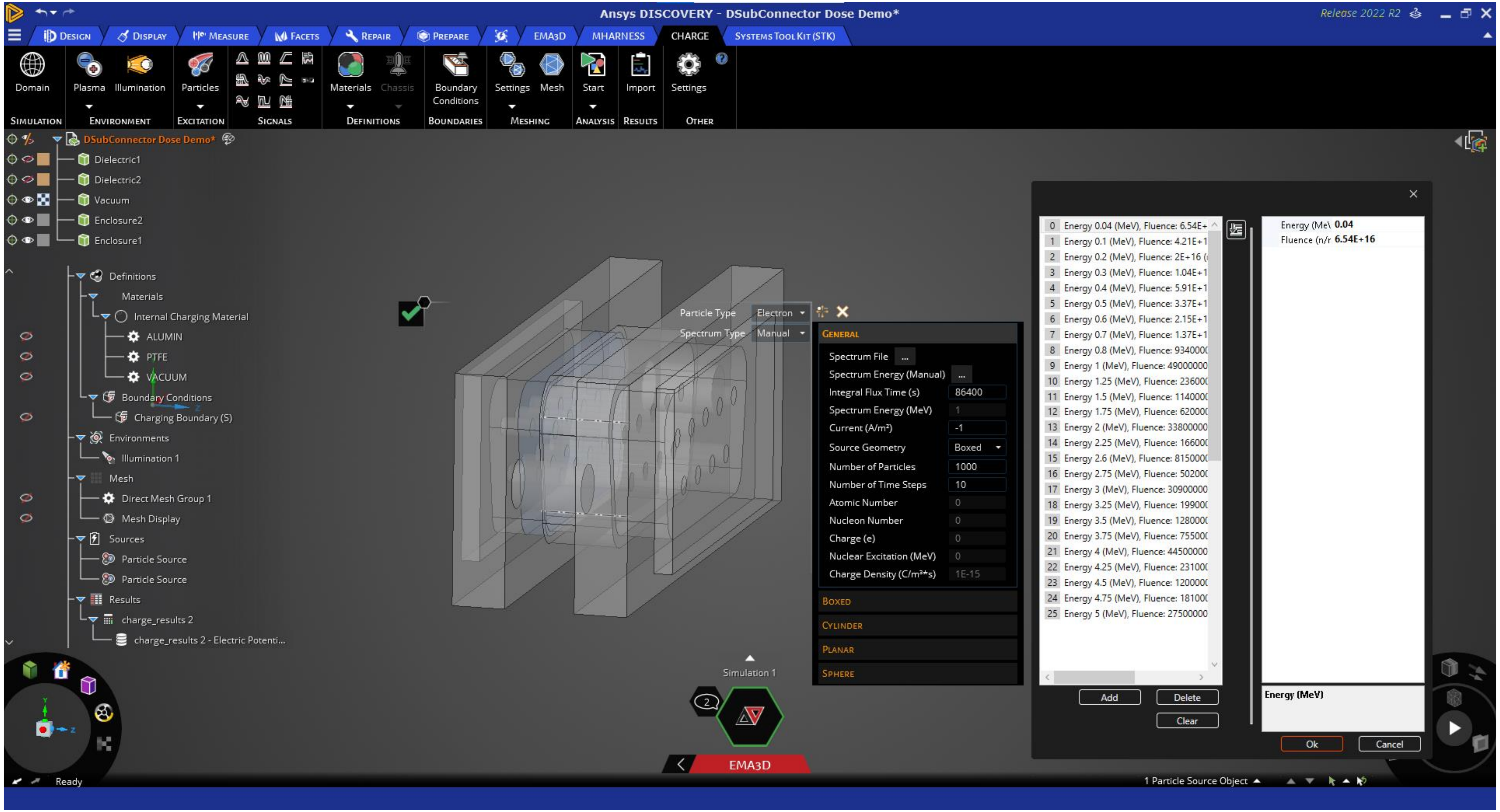


New Boundary Conditions for FEM

- Conductive, and Electric Field Boundary Conditions allow for more flexibility in setting up EM problem

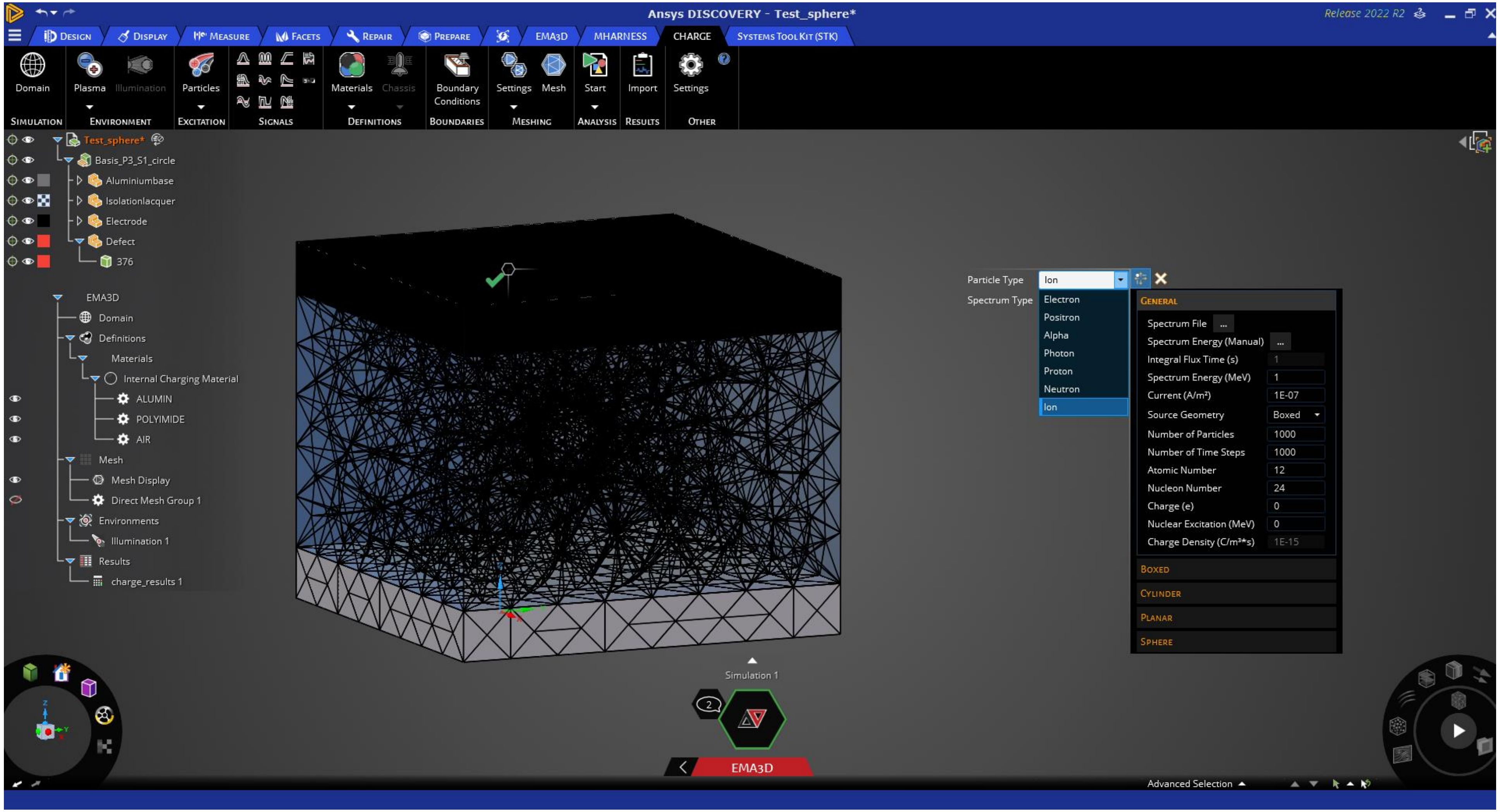


Particle Source Updates – Integral Fluence Inputs



Ansys

Particle Source Updates – Ions and Neutrons!



Ansys