



Fuel Cell Modeling at the Core of PEMFC Development

Phillip K. Schoch, PhD.
Senior Materials Scientist

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Pursuing Wide Array of Applications

GenDrive



Series 1000 Fuel Cells
Class 1 material handling power.



Series 2000 Fuel Cells
Class 2 material handling power.



Series 3000 Fuel Cells
Class 3 material handling power.

ProGen



Light Duty
Zero-emissions solutions for warehouse equipment manufacturers producing products like AGVs, small robotics, and aerospace UAVs.



Medium Duty
Delivery vans or light/medium duty cargo trucks used for on-road middle-mile delivery.

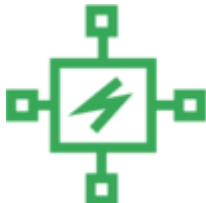


Heavy Duty
On-road trucking fleets for high utilization last-mile delivery or long-haul trucking.

GenSure



Data Centers
Scalable, zero-emission backup power serving the insatiable global need for data storage.



Microgrid
Sustainable backup power adding to the energy security of today's grid-tied or islanded microgrids.

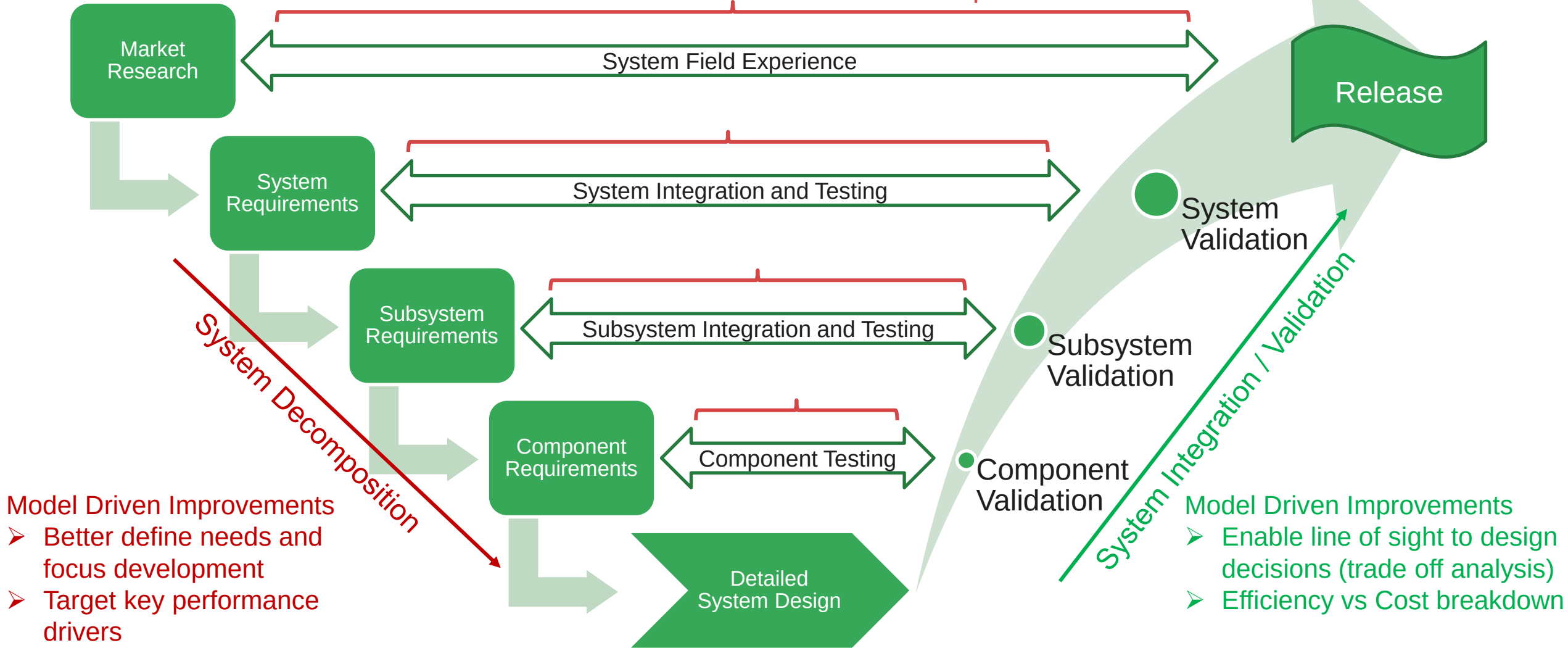


Telecom
Superior reliability for critical communication networks where uptime is profit and a phone call can be life-saving.



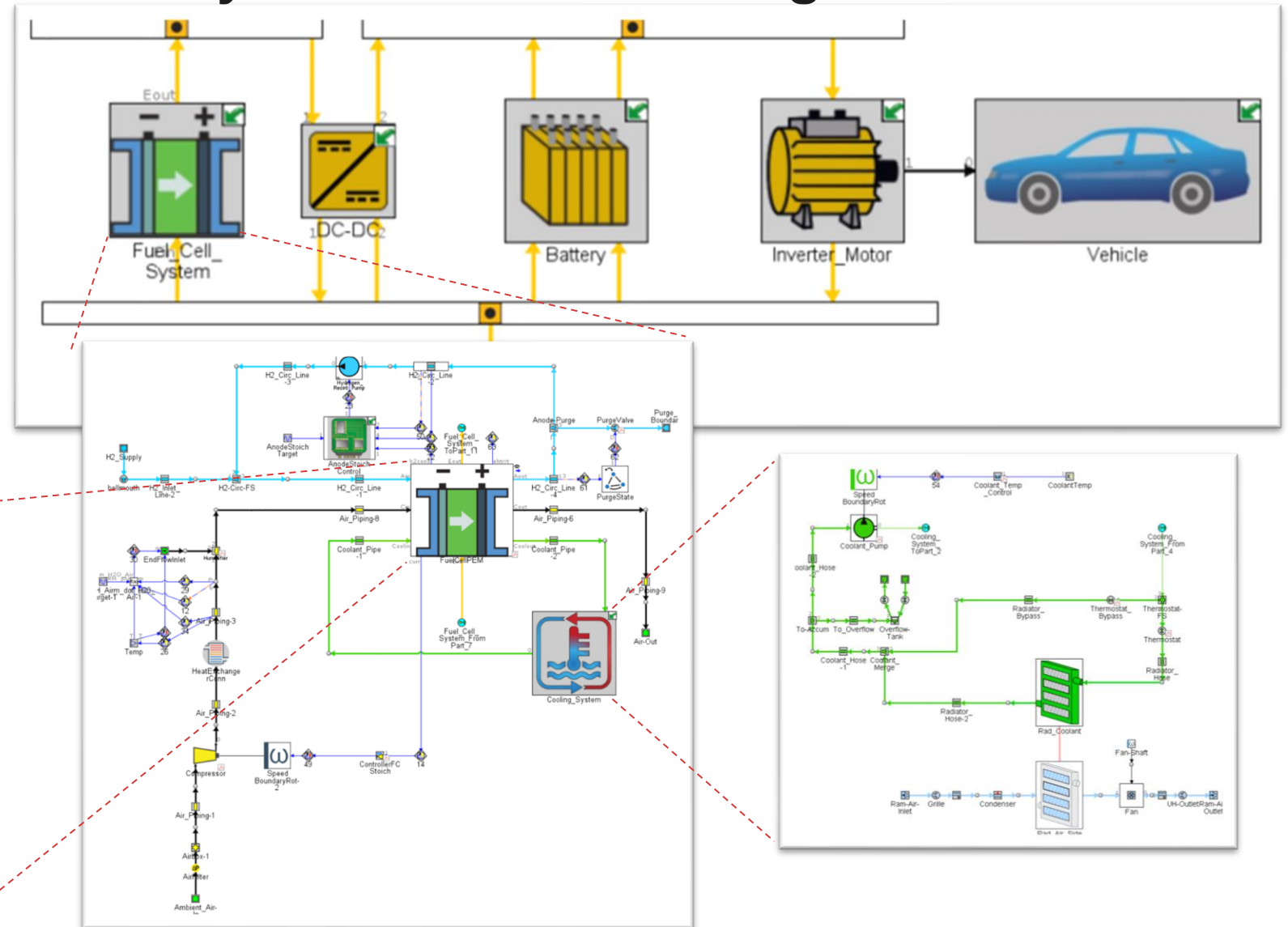
Innovating Our Development Cycle

Efficient Use of Models Minimizes Feedback Loop Timescale

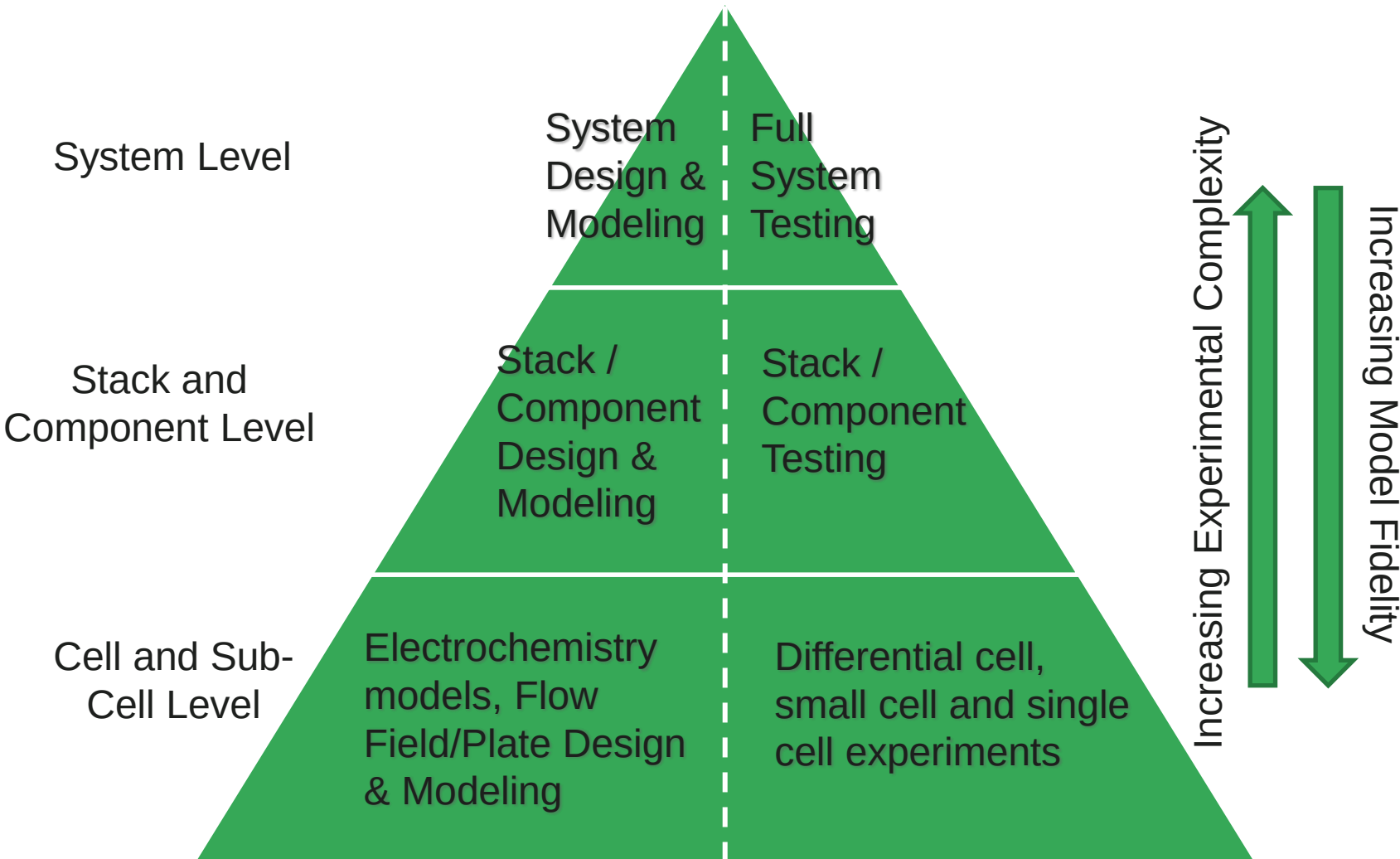


Multi-Scale: From single cell to stack to combined system

Multi-Physics: Convective and Diffusive Flow, Thermal, Electromagnetic, and Mechanical



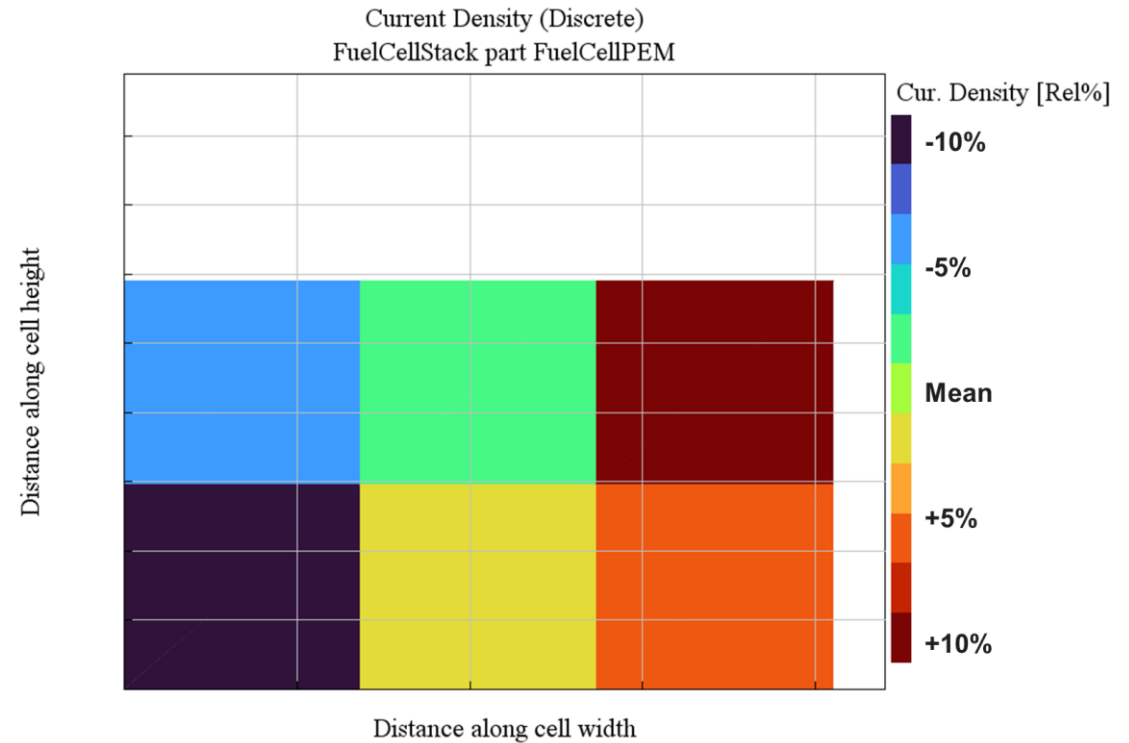
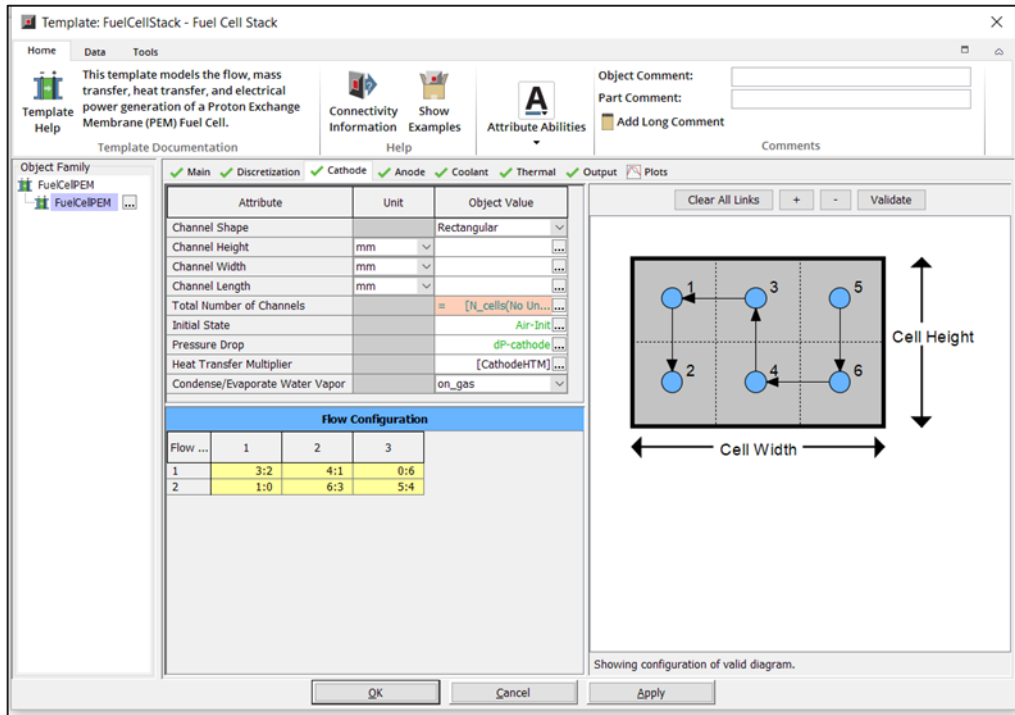
Design, Modeling and Experimentation Work Cohesively



Ultimate Goals:

- Better Design of Systems (BOL to EOL)
- Enable Hypothesis Testing/Targeted Experimentation
- More Efficient Use of Experiments
- Reduced Scale of Experimental Needs
- Increased Collaboration and Transparency across Engineering Teams
- Faster Conceptualization and Design of New/Novel Systems

Stack Model Results – Built-In Discretization

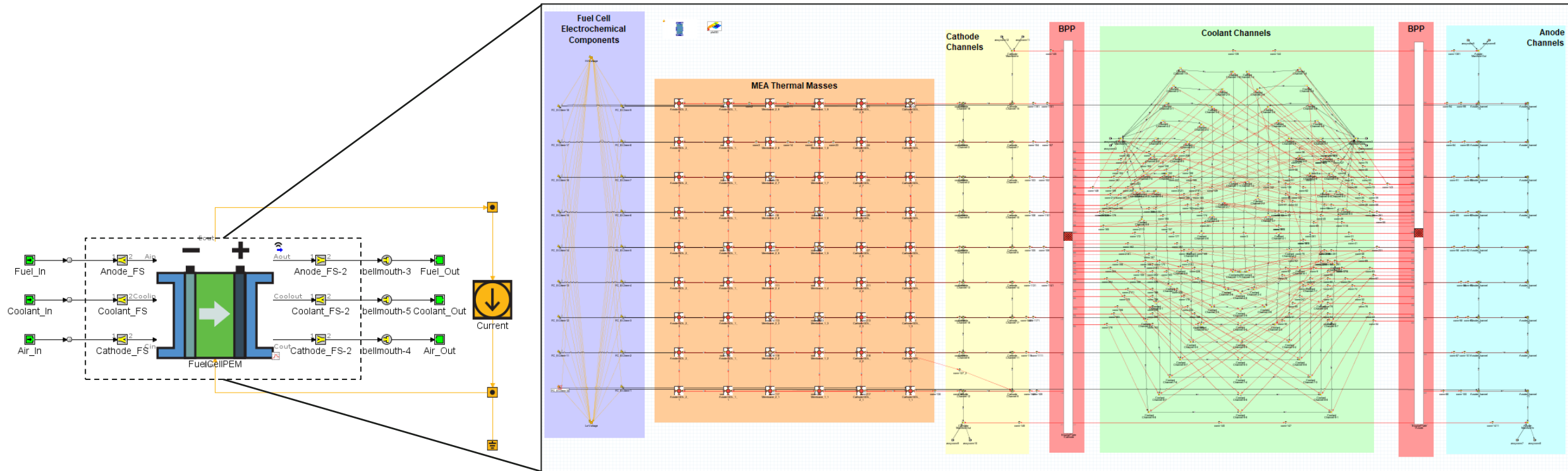


Discretization of Flow Field:

- Discretization of flow field possible with built in GT Widget, or 3D-1D GEM3D conversion of plate geometric data.
 - ❖ Enables analysis of localized cell performance (Hotspots, Starvation, Flooding).
 - ❖ Not intended for system level modeling as it extends model execution time by ~3.4x.
- Discretization limited by widget restrictions to single node inlet and outlet for anode/cathode
- Domains larger than desired for integration with small cell and differential cell work
- ❑ Option to customize discretization via CAD, GEM3D mapped to GT-ISE

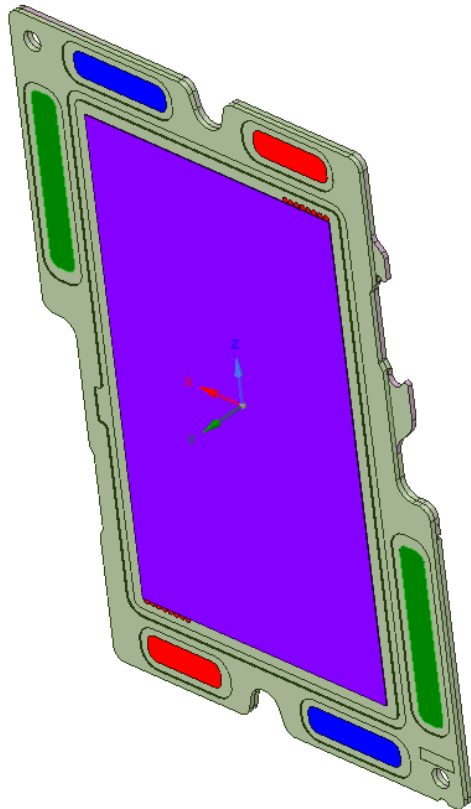
GenDrive Stack – GEM3D Discretization

Alternate method to discretization break apart Fuel Cell template into constituent components:
Electrical connections, MEA Thermal Masses, Cathode Channels, Cathode Bipolar Plate, Coolant Channels, Anode Bipolar Plate, Anode Channels



GenDrive Stack – Extracting Plate Data

Bipolar Plate Extracted Flow Volumes



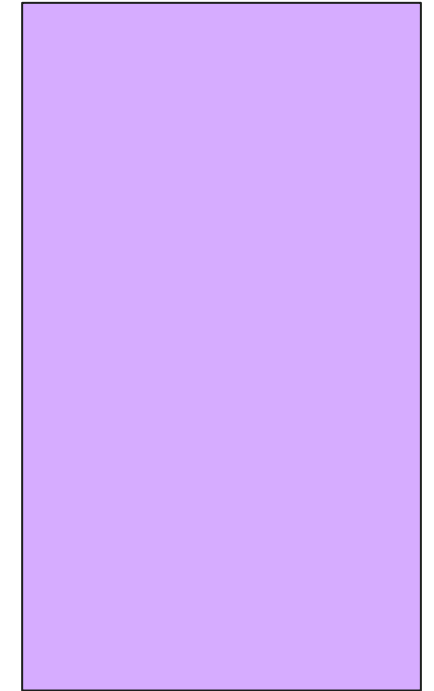
Cathode Flow Field



Anode Flow Field



MEA Area



GEM3D works directly from CAD files to extract flow field information

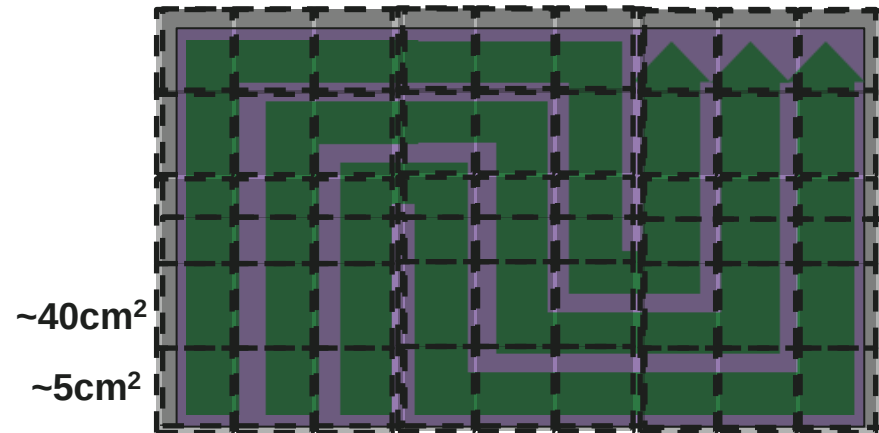
GenDrive Stack – Deep Discretization

With flow volumes extracted, discretization planes are needed

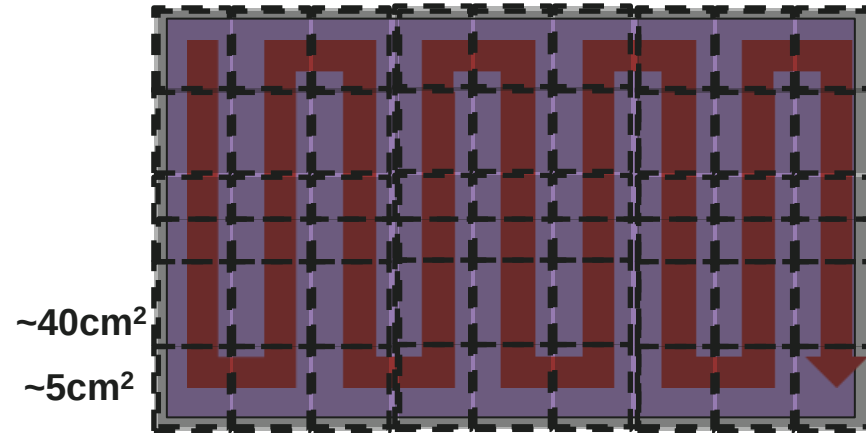
Options:

1. Equal area sections agnostic to anode/cathode flow lengths (previous 2x3)
2. Equal area sections focused on anode symmetry (5x9)

Cathode



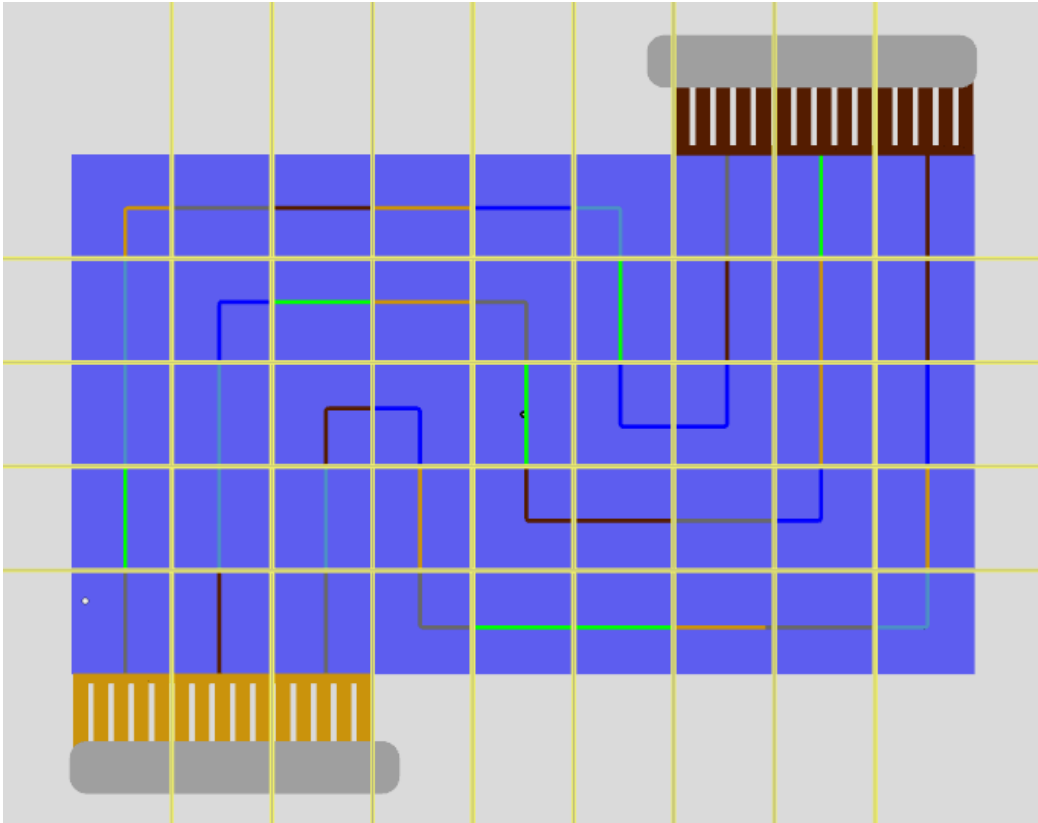
Anode



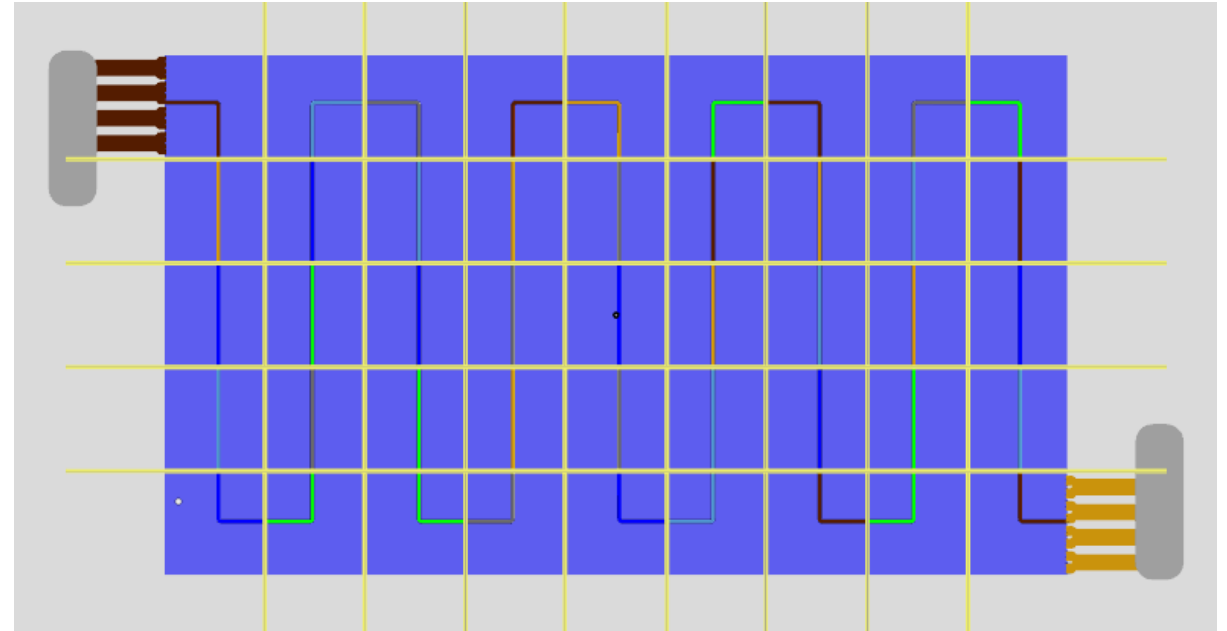
Deep Discretization – Channel Mapping to MEA Areas

Single Cathode and Anode channel used in each MEA discrete area, modeled as multiple identical channels

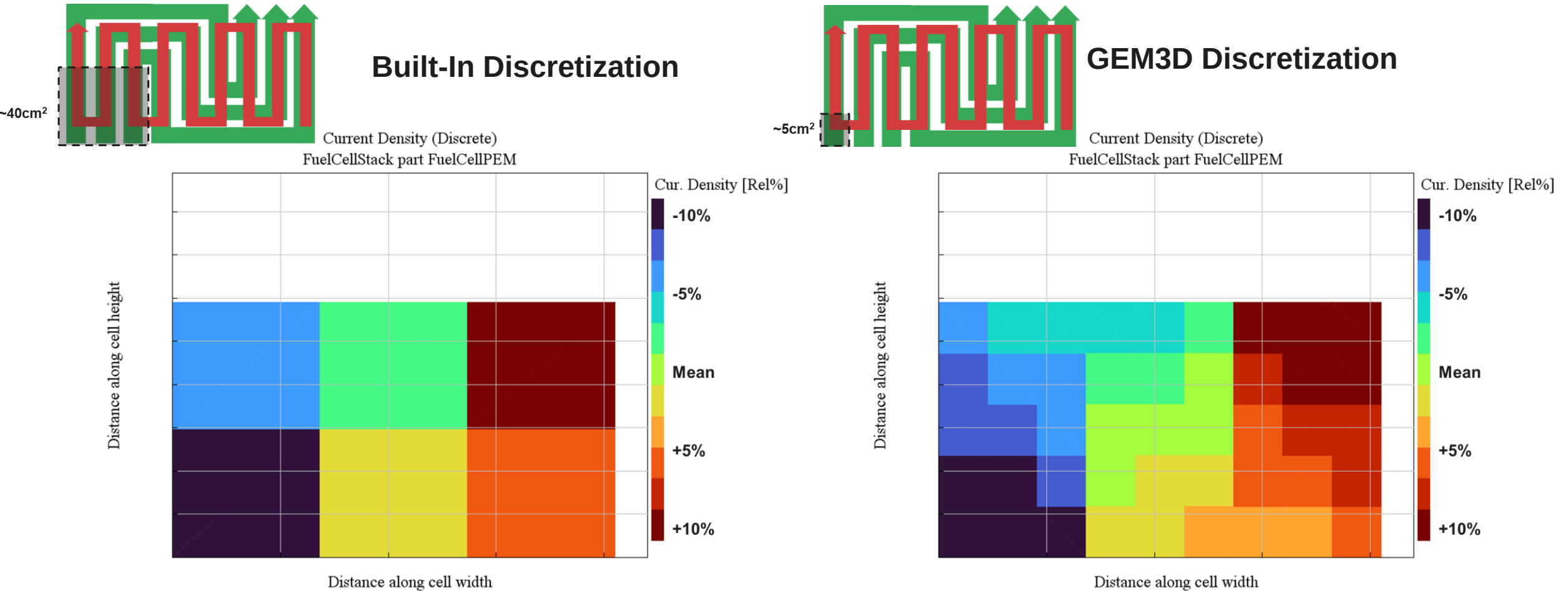
Cathode



Anode



Deep Discretization Results vs Built-In Widget



- Deep Discretization via CAD and GEM3D allowed for customizable resolution and finer sensitivity to local conditions

Summary and Outlook

- Plug innovating our approach to system development by incorporating multi-physics modeling
- GT-SUITE enabled PEMFC stack integration in single simulation environment
- Capabilities good fit for incorporating PEMFC stack into Fuel Cell plant and total system model
- Recent work examined potential for fuel cell area discretization via two methods:
 1. Built-in widget to GT-ISE
 2. CAD, GEM3D mapping method to GT-ISE
- ❑ Built-in widget has existing limitations reducing potential value in mapping area specific flow behavior
- GEM3D method, though tedious, offered significant customization
- Enabled discretization relevant to small cell and differential cell experimentation





Green Hydrogen at Work™