

# Light-weight, Low Cost PEM Fuel Cell Stacks

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# Project Overview



DOE Hydrogen Program

## Timeline

Start Date: April 2007

End Date: October 2009

% Complete: 35%

## DOE Barriers Addressed

### B. Stack Cost:

Substantially different stack design, materials and assembly

### C. Performance:

Lower W/cm<sup>2</sup>, but higher kW/kg through minimization of stack weight and BOP requirements

## Budget

Total Funding: \$1.06 M

DOE: \$846K

Cost Share: \$212K

FY07 funding: \$400K

FY08 funding: \$350K (est)

## Collaborators

Endura Plastics, Inc.

# Project Objectives



DOE Hydrogen Program

- **Demonstrate edge collected stack design capable of >1 kW/kg (system level)**
  - **DOE 2010 targets: 2 kW/kg (stack), 650 W/kg (system)**
  
- **Develop low cost, injection molded stack components**
  - **DOE 2010 targets: \$25/kW (stack), \$45/kW (system)**
  
- **Verify stack performance under adiabatic conditions**
  - **DOE 2010 target: 55% stack efficiency at rated power**
  
- **Accelerate stack development by incorporation of multiple cell level sensors within the stack coupled with CFD modeling**

# DOE Technical Barriers Addressed



DOE Hydrogen Program

## B. Cost:

- Known manufacturing processes – printing, injection molding
- Low parts count, easier assembly
- Eliminate costly bipolar plates, GDLs

## C. Performance:

- Light weight stack components
- Minimal balance of plant – lower parasitic losses
- Lower  $W/cm^2$ , but higher kW/kg

## A. Durability/Reliability:

- Series/Parallel Sub-stacks for higher reliability
- Design allows for membrane expansion with lower stress
- Minimal balance of plant
- No impact on durability issues related to impurities

# Project Summary



DOE Hydrogen Program

- **Relevance:** Our stack design is intended to significantly reduce materials cost and to promote ease of manufacturing and assembly
  
- **Approach:** A combination of molded plastic components and direct fabrication via printing to yield a stack with a very low parts count.
  
- **Progress:**
  - Single cell testing looks reasonable – could be better
  - Molds being re-worked – sub-stack testing delayed
  
- **Future Work:**
  - within the next 3 months, fabricate first generation sub-stack



# Future Work:

- **Continue Single Cell testing**
  - **Optimize Collector properties**
  - **Correlate test results with CFD predictions**
  
- **Refine CFD model – anode assumptions**
  
- **Fabricate first generation sub-stack**
  - **Combining single cell results with initial molded part weights suggests sub-stack could achieve 1500 W/kg**

# Go / No-Go Decisions



DOE Hydrogen Program

- G1 – sub-stack to prototype stack
- at 18 months
- basis: sub-stack performance  $>500$  W/kg
  
- G2 – 1 kW stack fabrication
- at 24 months
- basis: do prototype stack results predict system level specific power  $>500$  W/kg?

# Conventional Bipolar Stacks vs Edge Collected Stacks



DOE Hydrogen Program

## Bipolar

- minimal iR loss in bipolar plates
- more seals required – gasketing at the cell level
- higher parts count - CCM, GDL, gaskets, plus bipolar plate, plus endplates/tie-rods
- Substantial weight in in-active components
- Thick GDL required to obtain reactant distribution over ribs, significant transport losses in GDL
- significant Compressive force needed to obtain good seals, low resistance interfaces

## Edge Collected

- iR loss can be significant
- Lower pressure drop possible
- Fewer seals, one gasket can envelop multiple cells
- lower parts count
- Avoids ribbed flow field, much thinner GDL possible



# Task 1 and 4



DOE Hydrogen Program

## Current collectors and Interconnects

### Status:

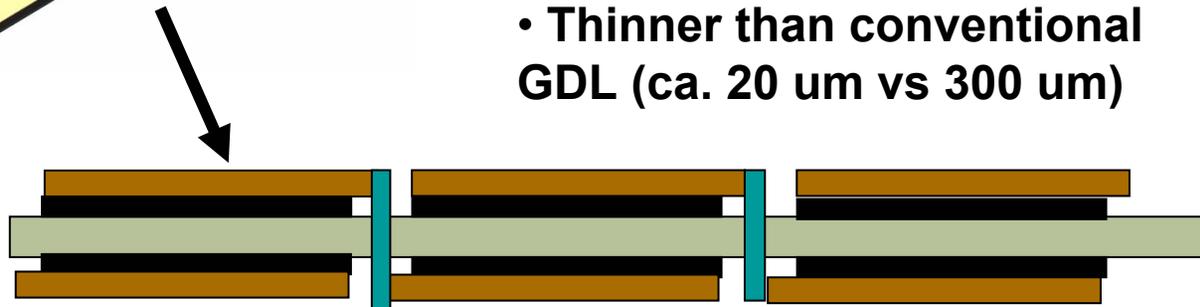
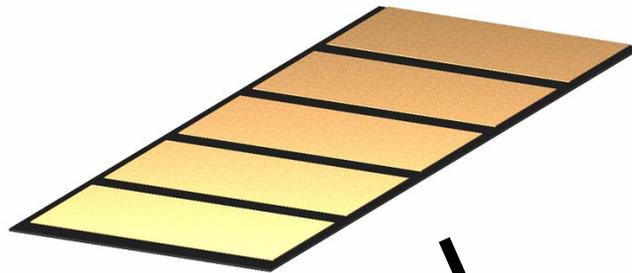
- Acceptable conductivity, porosity demonstrated
- Hydrophobicity needs improvement (?)
- Long term stability with humidity cycling to be evaluated (summer undergrad project)
- Have not evaluated spray/electro-spray to date – only screen printed inks

# Task 1 and 4

## Approach

### Printed current collectors for edge collection

- Highly conductive
- Strongly adherent
- Porous for reactant transport
- Tailored hydrophobicity/hydrophilicity
- Thinner than conventional GDL (ca. 20  $\mu\text{m}$  vs 300  $\mu\text{m}$ )



Interconnect



Collector



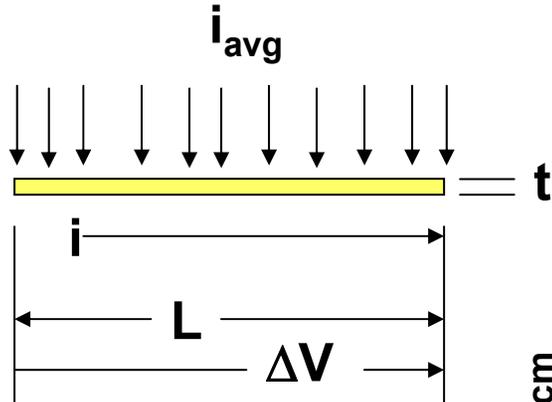
Membrane



Electrode

# Task 1: Limit On Electrode Length For Edge Collection

Allowable Current Collector Length for 10 mV loss



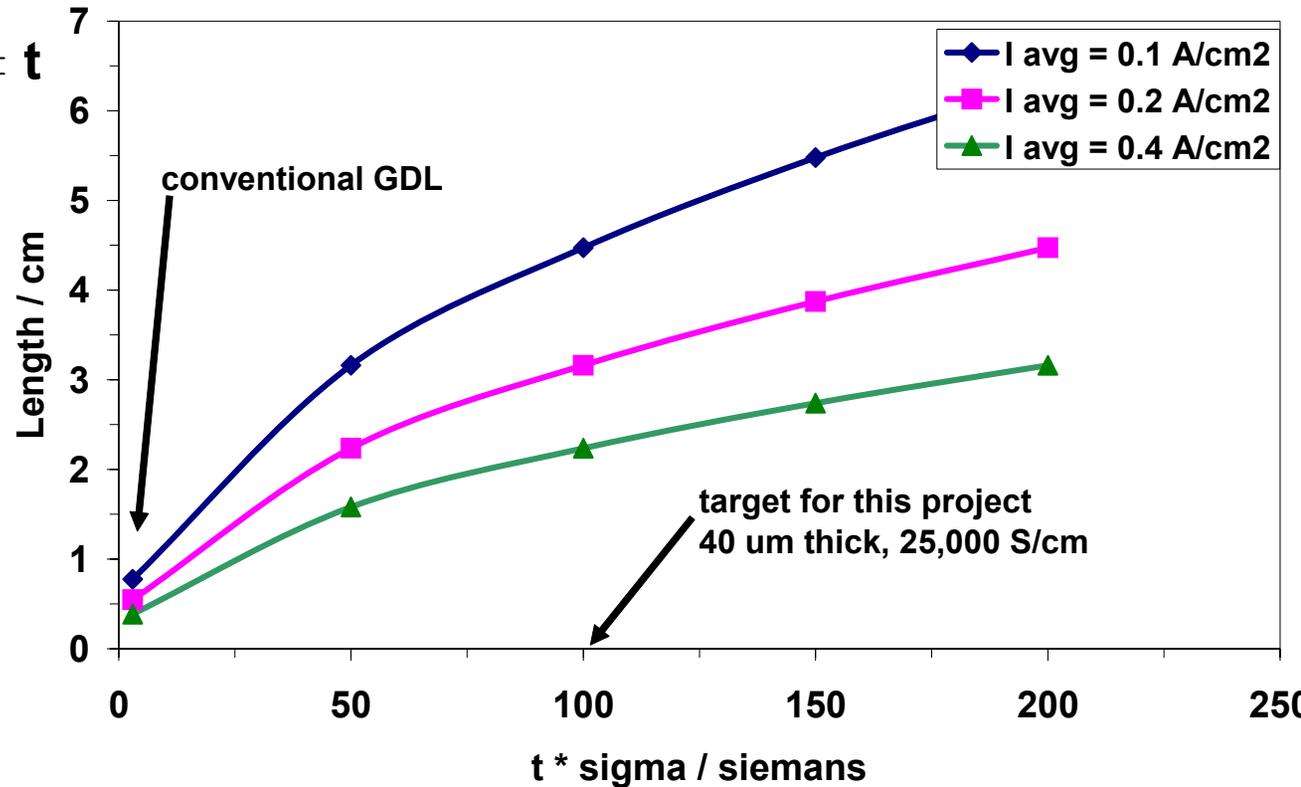
$$L = \left\{ \frac{2\Delta V(t \cdot \sigma)}{i_{avg}} \right\}^{1/2}$$

$\sigma$  - conductivity

$\Delta V$  - voltage loss

$t$  - collector thickness

$L$  - collector length



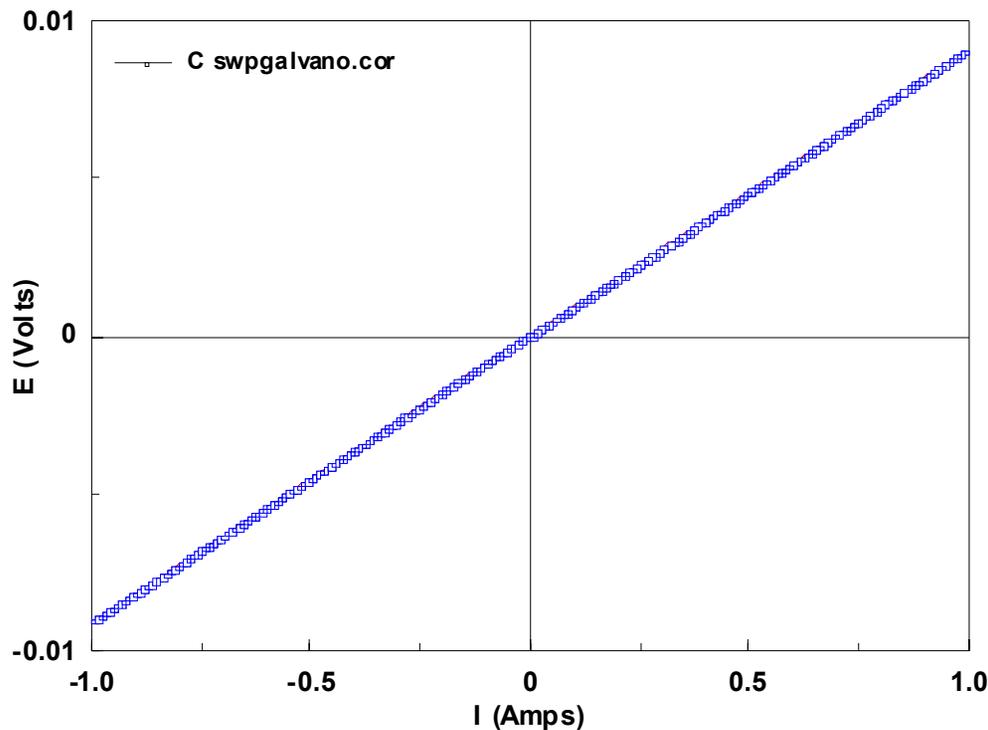
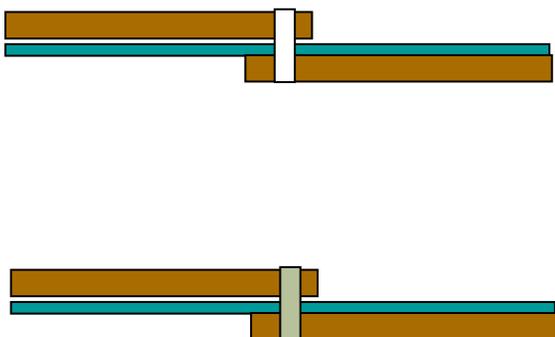
# Task 1: Technical Results



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## Printed Current Collectors / Interconnects

- Silver based ink – 27,000 S/cm
- Vias laser drilled – 1 mm dia., 6 vias spaced evenly over 1 cm width
- Resistance = 0.009 ohm



# Task 2

## Gaskets

### Status:

- Seal problems have been an issue in single cell tests, and sub-stack flow testing
- Intent for some sub-stack and stack fuel cell tests is to ultrasonically weld the assembly – eliminating the need for tie-bolts and gaskets – but this will prevent convenient disassembly

# Task 3



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## Surface Tension Controlled Microfluidics

### Status:

- Task set aside early in project
  - Student not available
  - Performance of early trials too far off projections to be viable for first generation tests

# Task 5

## CFD modeling



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Status:

- Single cell simulations
  - Cathode kinetics, water transport, membrane conductivity included
  - Anode kinetics ignored
- Predict current density variations for
  - Different inlet humidities
  - Different inlet flow rates
  - As a function of overall current density
- Single Cell Fuel Cell testing on-going using similar conditions

# Task 5

## CFD modeling



DOE Hydrogen Program



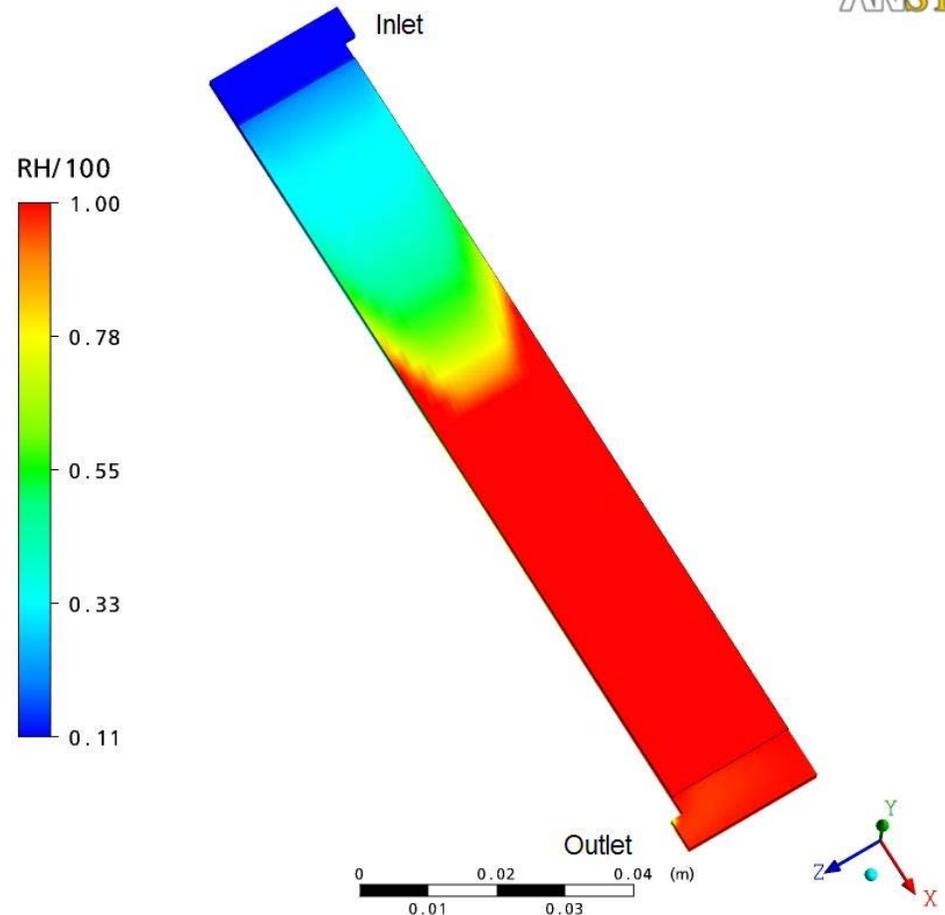
### Example Results:

**Dry Air at 2.5X stoich**

**100%RH H<sub>2</sub>**

**Avg. c.d. = 0.47 A/cm<sup>2</sup>**

**Bottom half of cell is saturated, constant current density**



# Task 5

## CFD modeling

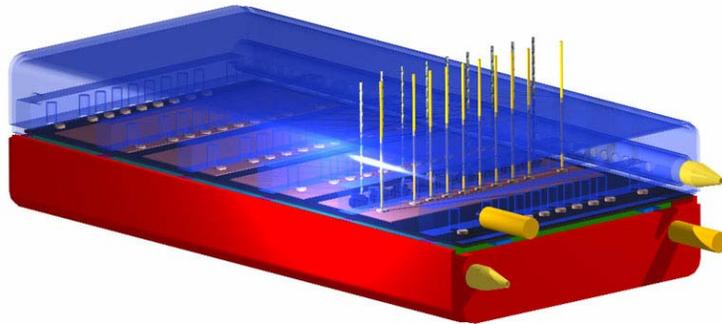


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### Issues:

- Anode side is averaged over inlet/outlet conditions ala Springer – cannot currently evaluate co- vs counter-flow effects
- Water transport through printed current collectors has not been well characterized.

## Sensor Integration for Rapid Design Evaluation



- Sub-stack design permits access to gas space above each cell
- Temperature, humidity, gas composition can be monitored
- Current collector can also be segmented to allow for measurement of local potentials
- Results used to evaluate/enhance CFD models

# Task 6



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## Design and Fab of Molded Parts

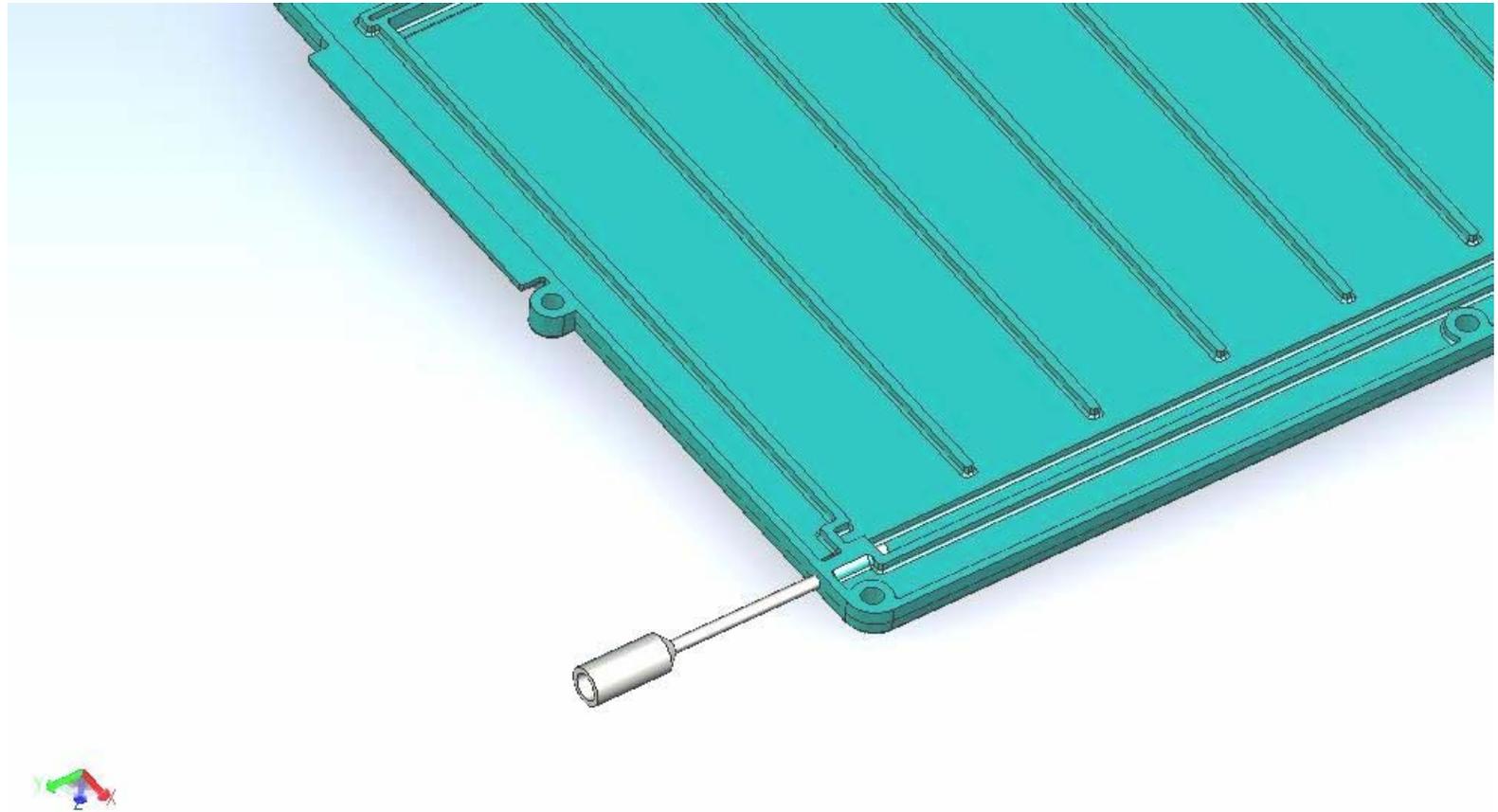
- 1<sup>st</sup> run – 11/16/07. High levels of stress – significant warpage when raised to operating temperature
- 2<sup>nd</sup> run – 12/7/08. Lower residual stress. Annealing at 88C relieves stress, part remains flat at operating temperature
  - inlet/outlet ports still not acceptable
  - Incorrect placement of through hole
- Production with re-designed mold originally scheduled for mid-Feb has been delayed until May



# Approach



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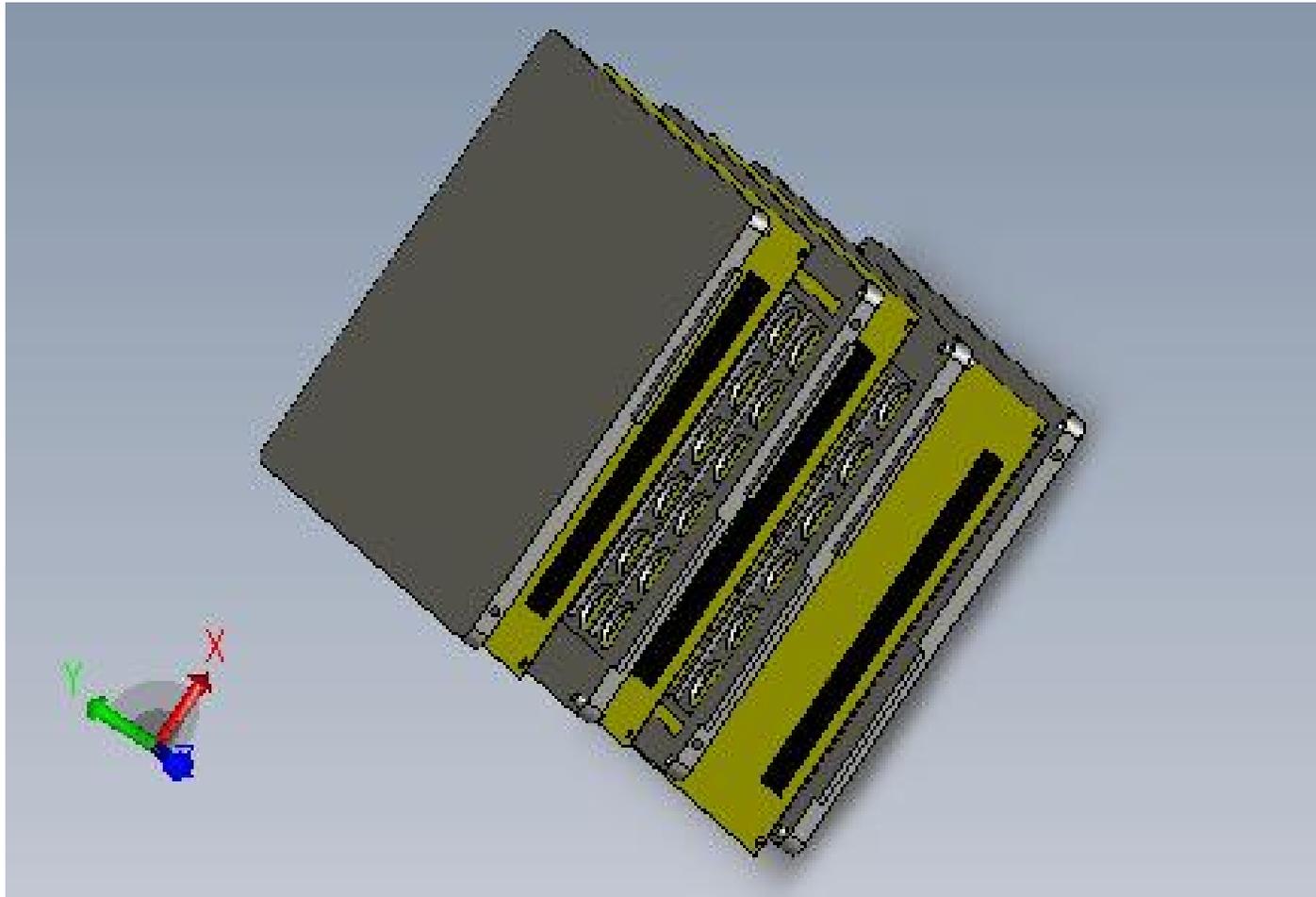
**Generation 1a design with modified bolt hole location and inset molded inlet/outlet tubes**

# Approach



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Exploded View of Short stack consisting of 3 sub-stacks

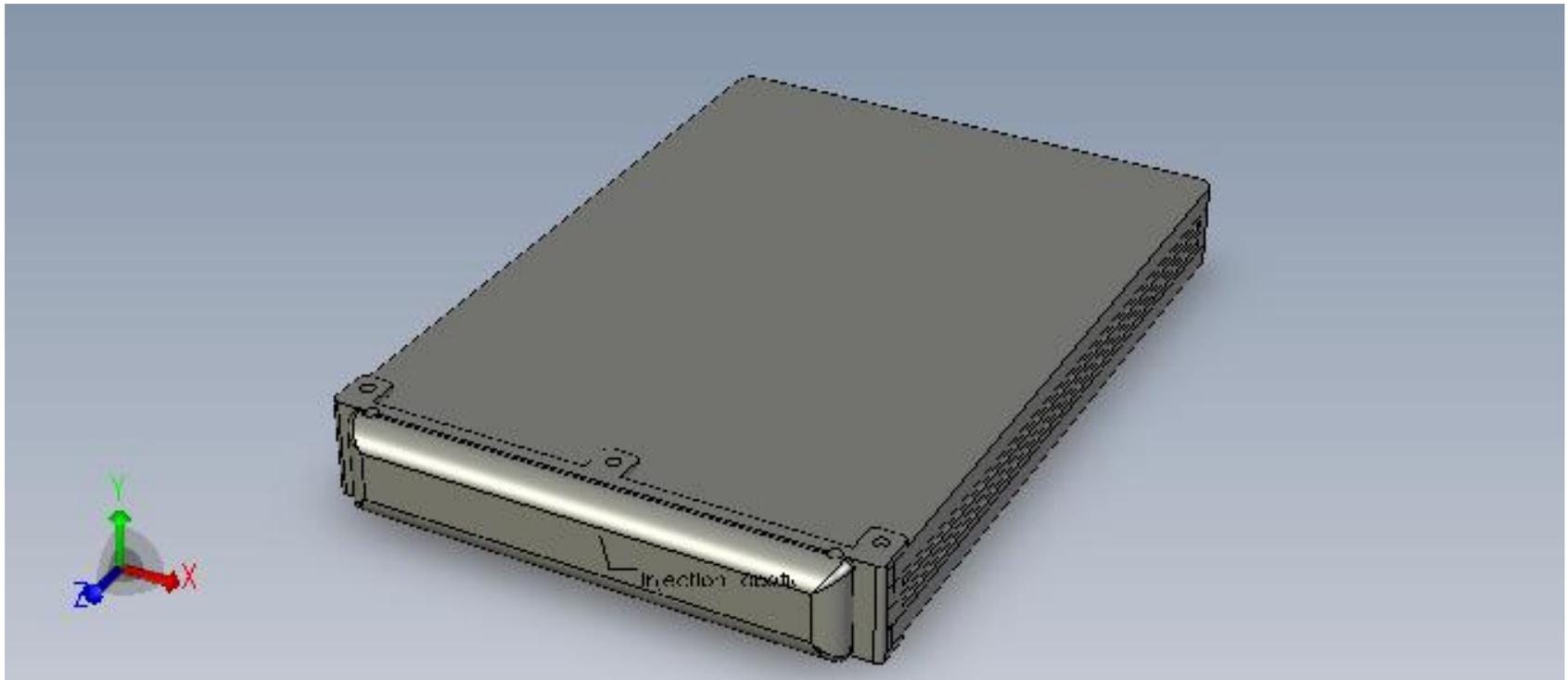


# Approach



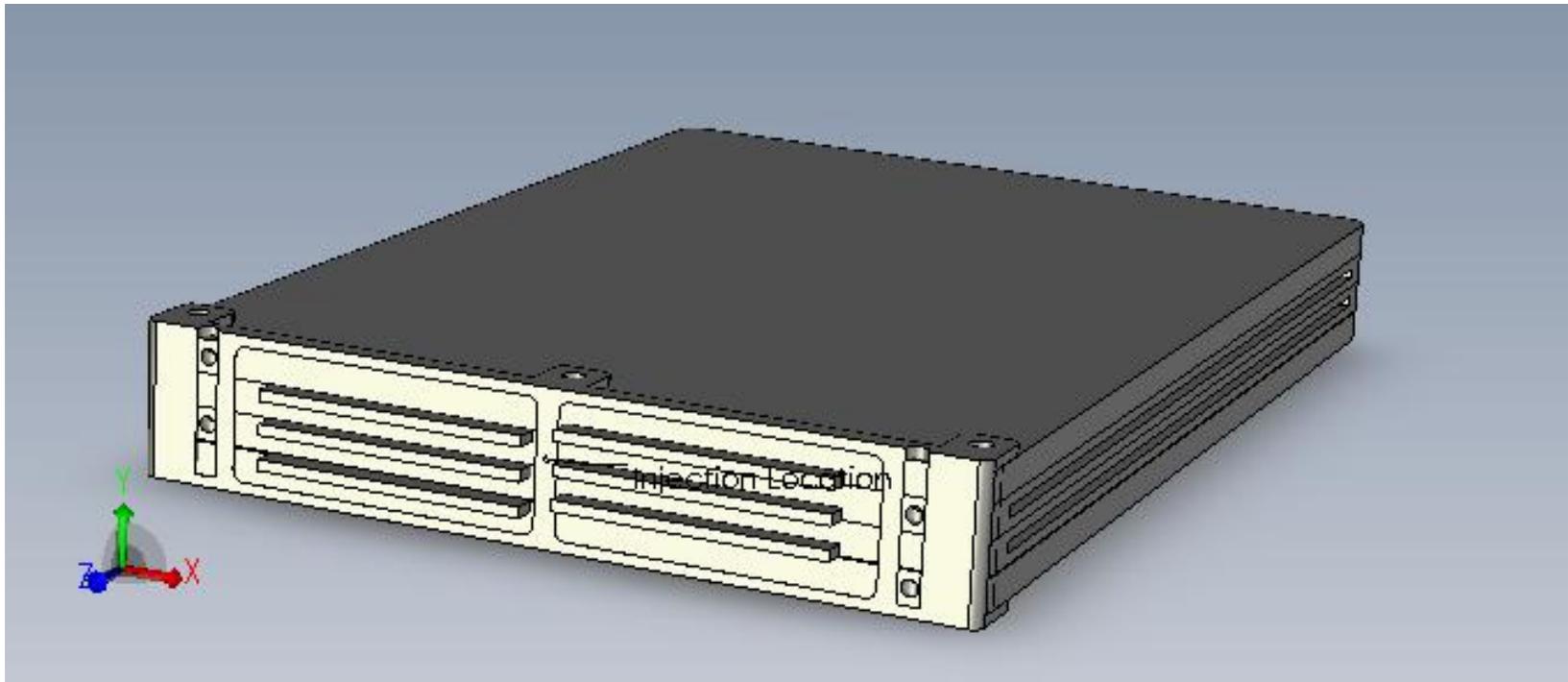
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## Conceptual View of Short Stack with Molded Manifold End Cap



# Approach

View w/o End Cap showing contact tabs and reactant ports



# Task 7

## Fuel Cell Testing



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- Single cell testing in progress
  - Effects of temperature, reactant flow rates and humidities
  - Evaluation of current collector inks in fuel cell environment
  - Evaluation of metallization options at the ends of a sub-stack
  - New graduate student was added to take over this area in mid-Jan



# Task 7

## Fuel Cell Testing



DOE Hydrogen Program

### Single Cell Test

Gore CCM with CWRU  
GDL

50C,

H<sub>2</sub> / Air

atmospheric pressure

Constant reactant  
flow

5 mV/s sweep

Power Density

= 0.3 W/cm<sup>2</sup>

