**DOE Fuel Cell Projects**
**Kick-off Meeting**

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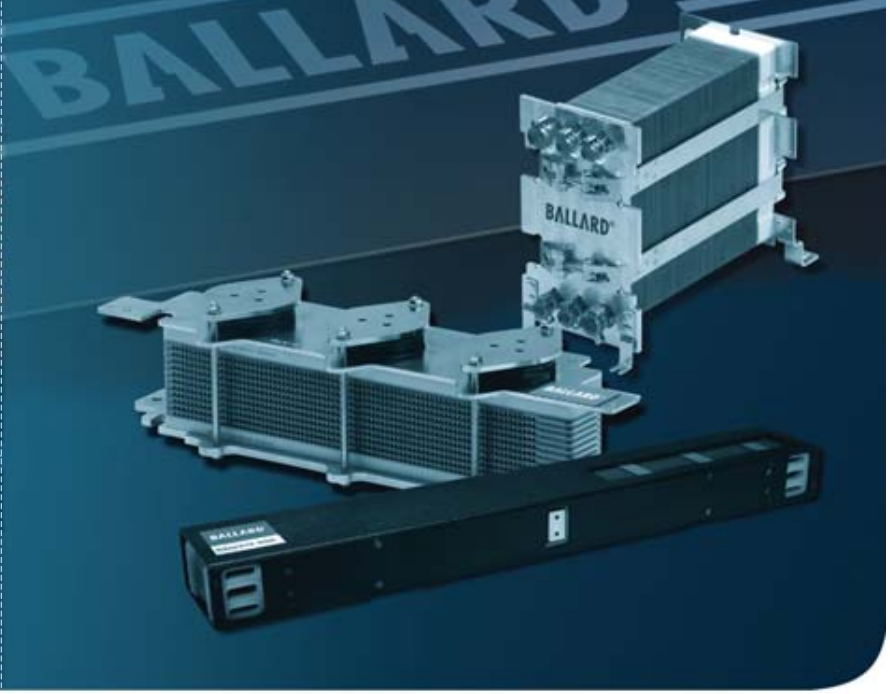
# Development of Micro-structural Mitigation Strategies for PEM Fuel Cells: Morphological Simulation and Experimental Approaches




BALLARD POWER SYSTEMS

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1 October 2009

# Project Objectives

- **Understand and quantify the fundamental degradation mechanisms**
  - Establish relationships between morphology, operational conditions, and the rate of catalyst/catalyst layer degradation
- **Understand the impact of degradation on the mechanical/chemical stability of the component interfaces, including the stability of the 3-phase interface**
- **Develop mechanistic, forward predictive kinetic and materials aging models for catalyst layer degradation**

- **Outcomes:**
  - Verified/quantified catalyst/catalyst layer degradation mechanisms, including coupling/feedback effects
  - Forward predictive models for catalyst layer aging
  - Mitigation “windows” for catalyst degradation

# Technical Barriers / Targets

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## Barriers:

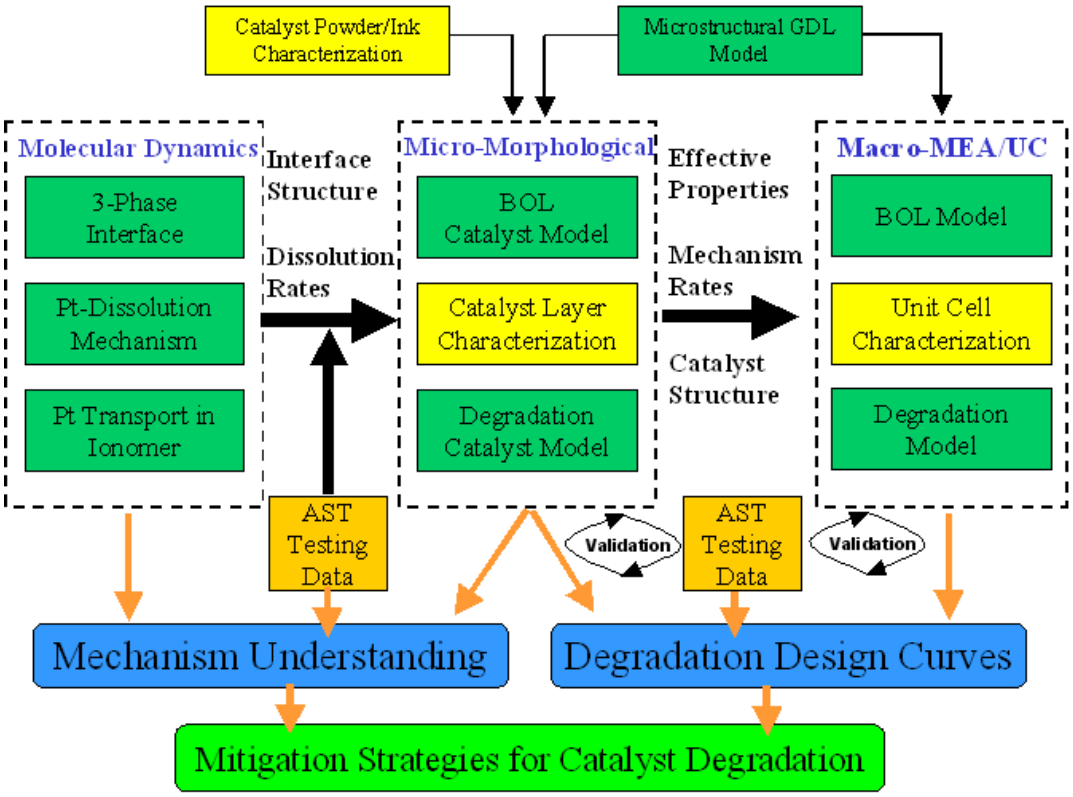
- Catalyst Layer Performance and Durability

## 2015 Targets

- Stationary Stack: $530/kW, 40,000 hrs (2011)
- Automotive Stack: $15/kW, 5000 hrs

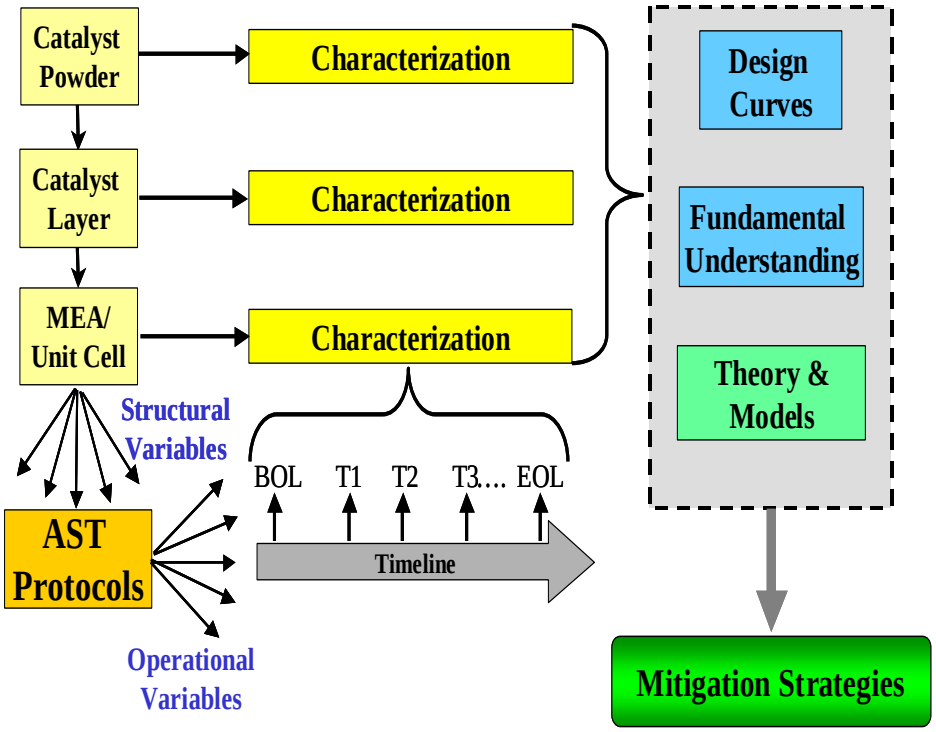
- MEA/Electrode Degradation:
  - Performance Loss : 5% over life (Power Density)
  - EPSA Loss: <40% (@0.2mg/cm$^2$ PGM total loading)
  - Catalyst Support Loss: <30mV after 100hrs @1.2V

# Approach
# Model Development



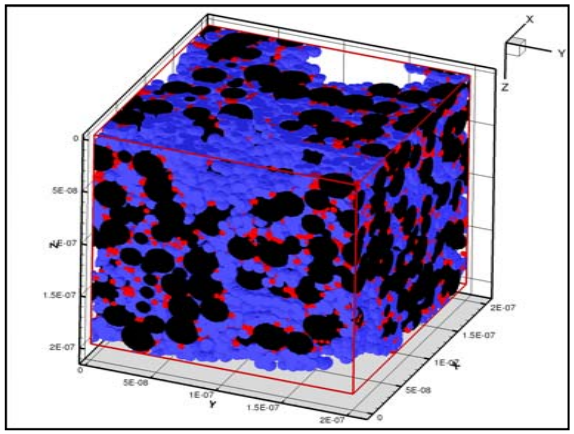

- **Molecular Dynamics**
  - Pt/Pt oxide dissolution mechanism
  - Pt ion transport in ionomer
  - Three-phase interface stability
- **Micro-Morphological**
  - Composition/Morphology effects
  - Local operating conditions effects
  - Variations in Material properties
  - Three-phase interface stability
  - Degradation Mechanism Rates
- **Macro-Unit Cell**
  - Inlet operating conditions effects
  - Effects of GDL properties

# Approach
# MEA Degradation & Characterization

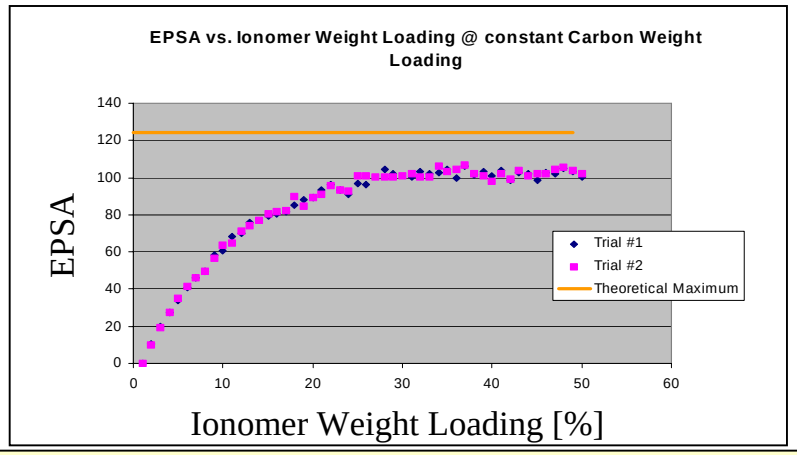



- **Catalyst / Catalyst Layer Degradation Quantification**
  - Material properties characterization
  - Progressive AST testing/ characterization
  - Catalyst layer composition effects
  - Inlet operation conditions effects
- **Correlation Development**
  - Catalyst/catalyst layer degradation rates
- **Mechanism Understanding**
  - Model validation data
  - Guide design/operational mitigations

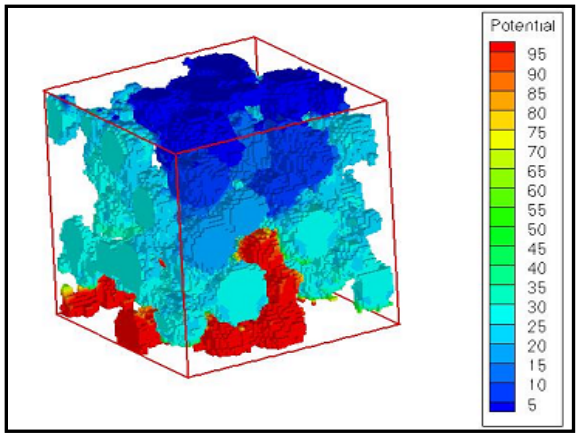
# Prior Work
# Micro-structural Catalyst Model



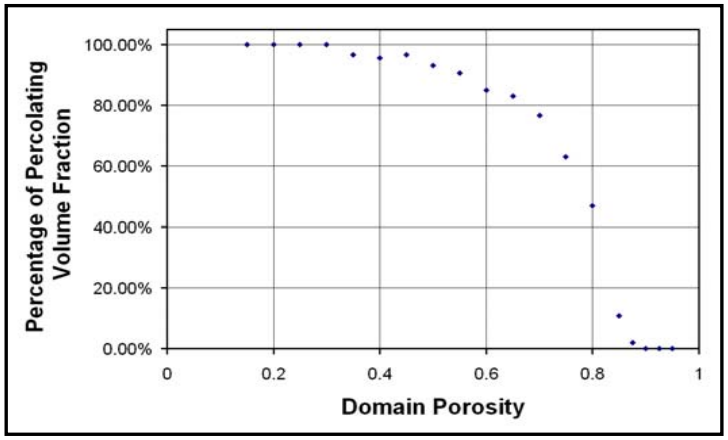
Model generated catalyst morphology




Model generated design curve for EPSA optimization

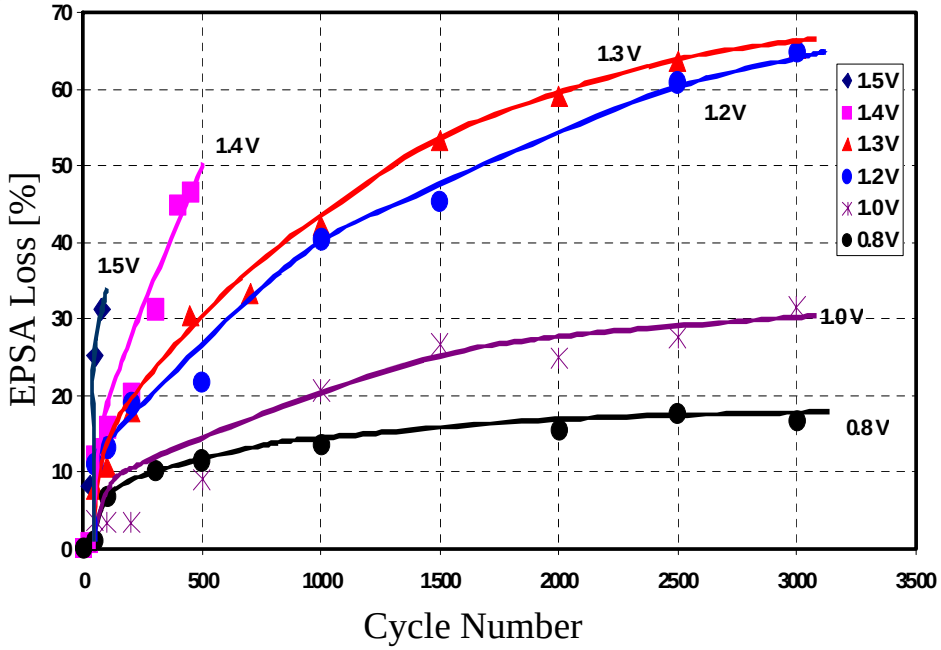


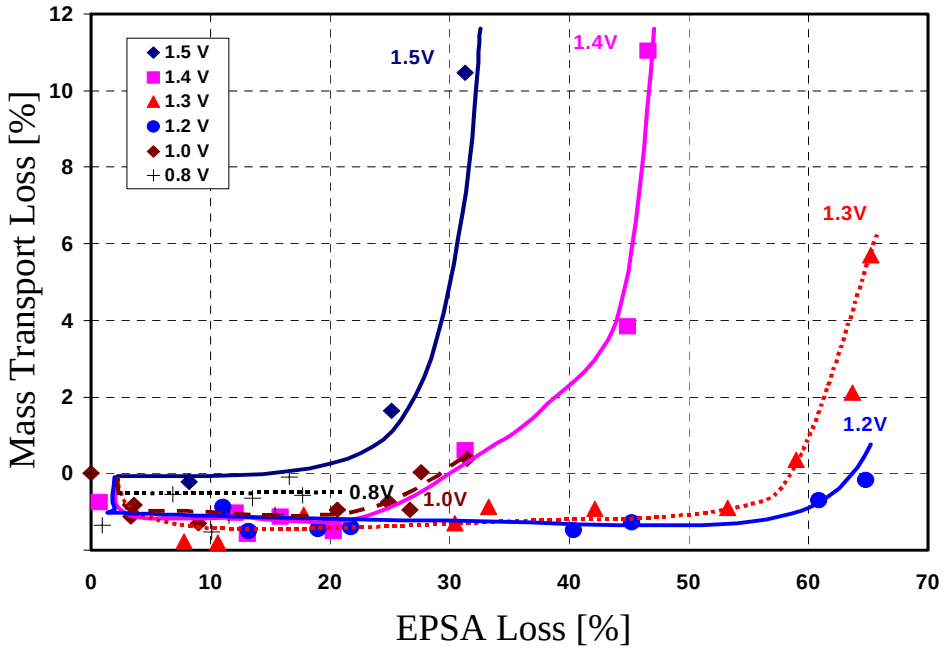

Electrical potential distribution




Model generated design curve for porosity optimization

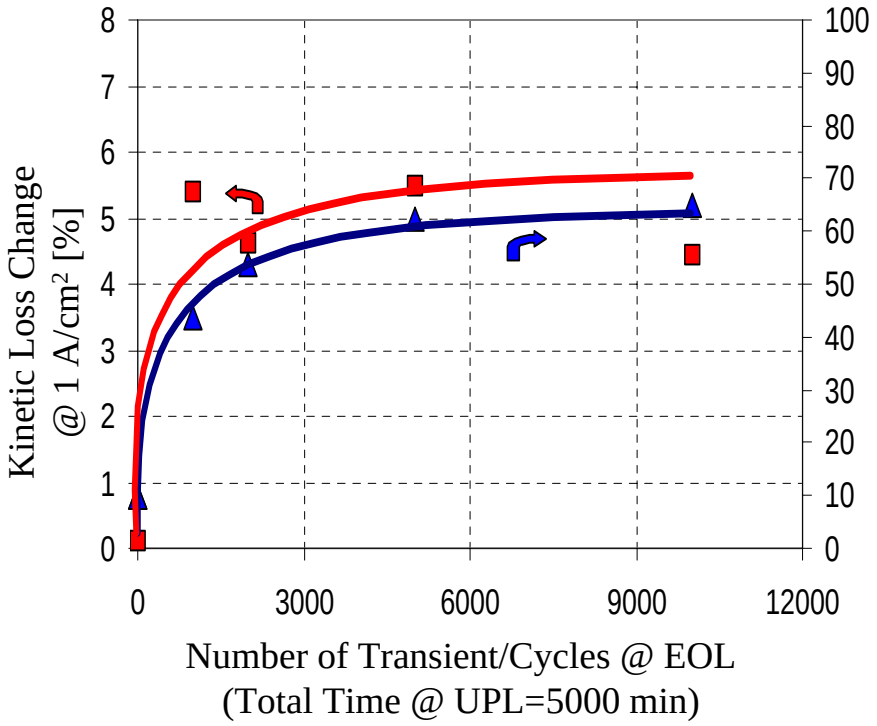
# Prior Work
# Accelerated Stress Testing (1)

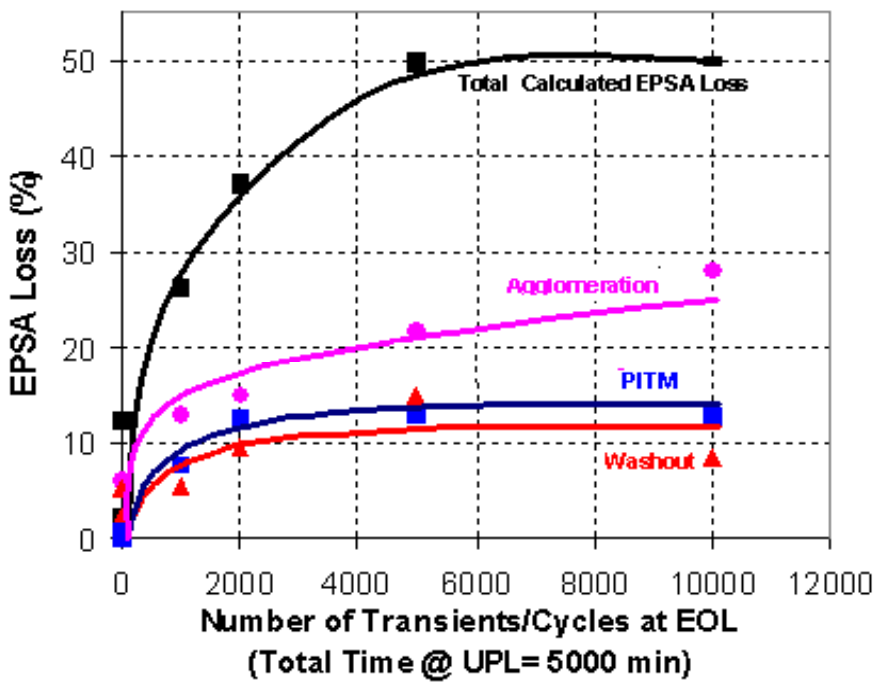



**EPSA / Mass Transport loss as a function of AST cycle number and upper potential**

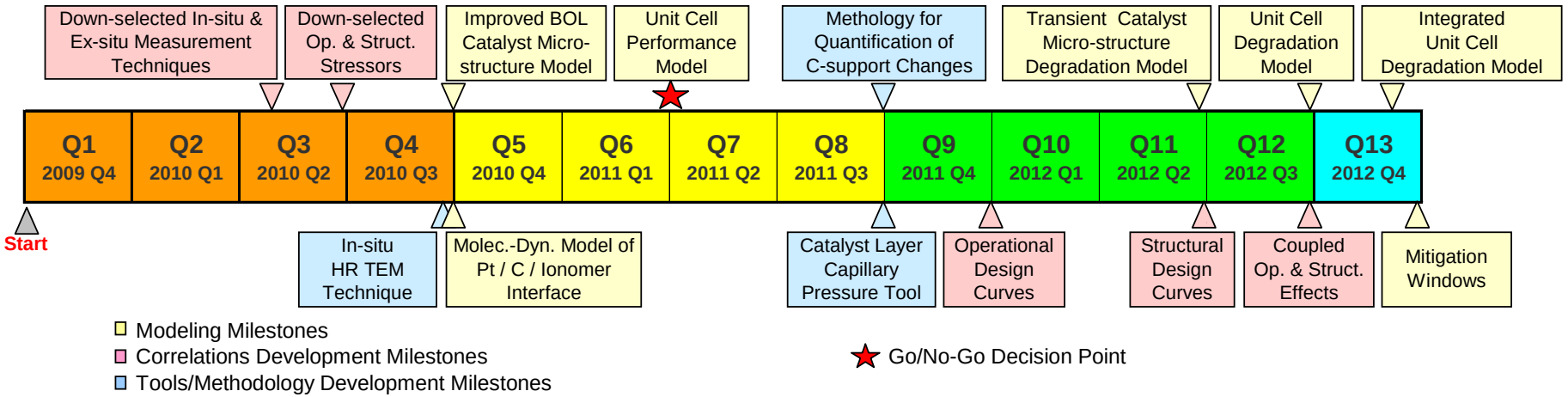
# Prior Work
# Accelerated Stress Testing (2)




**Kinetic / EPSA loss breakdown as a function of AST cycle frequency after 5000 minutes at UPL**

# Project Timeline – 3¼ Years




- Q6: Go/No-go Decision to Continue Project
  - **Validated statistically generated Unit Cell Model performance curve**
- Other Decision Points:
  - Q4: Validated BOL Micro-structural Catalyst Model predictions
    In-situ HRTEM technique for AST testing
  - Q8: Capillary Pressure tool for measurement of catalyst layers
    Technique/methodology for quantifying carbon support changes
  - Q10: Validated Transient Model predictions vs. AST-degraded catalyst layers
  - Q11: Validated statistically generated Unit Cell Model degradation curves

# Organizations / Partners

- **Ballard Material Products / Ballard Power Systems (S. Wessel, D. Harvey, V. Colbow)**
  - Lead: Micro-structural/MEA/Unit Cell modeling, AST correlations, characterization, durability windows
- **Queen's University – Fuel Cell Research Center (K.Karan, J. Pharoah)**
  - Micro-structural Catalyst Layer/Unit Cell modeling, catalyst characterization
- **Georgia Institute of Technology (S.S. Jang)**
  - Molecular modeling of 3-phase Interface & Pt dissolution/transport
- **Los Alamos National Laboratory (R. Borup, R. Mukundan)**
  - Characterization of catalyst layer/GDL
- **Michigan Technological University (J. Allen)**
  - Capillary pressure and interface characterization, catalyst layer capillary pressure tool development
- **University of New Mexico (P. Atanassov)**
  - Carbon corrosion mechanism, characterization of catalyst powder/layers

# Budget

| Receipients | FY 2010<br>Oct 09 - Sept 10 | FY 2011<br>Oct 10 - Sept 11 | FY 2012<br>Oct 11 - Sept 12 | FY 2013<br>Oct 12 - Dec 12 | Total |
|---|---|---|---|---|---|
| Ballard | $1,203,481 | $1,201,481 | $1,216,676 | $18,507 | $3,640,145 |
| Collaborators | $757,837 | $769,984 | $811,914 | $33,410 | $2,373,145 |
| **Total Project Costs** | **$1,961,318** | **$1,971,465** | **$2,028,590** | **$51,917** | **$6,013,290** |
| **Receipients Cost Share** | **$439,086** | **$441,697** | **$448,186** | **$11,470** | **$1,340,439** |
| **DOE Cost Share** | **$1,522,232** | **$1,529,768** | **$1,580,404** | **$40,447** | **$4,672,851** |